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Water Impoundments for Wildlife: A Habitat Management Workshop

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WATER IMPOUNDMENTS FOR WILDLIFE: A HABITAT MANAGEMENT WORKSHOP

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Program Chairman:
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PREFACE

In 1974, a multi-disciplined research program on wildlife water-impoundments was implemented by the North Central Forest Experiment Station, U.S. Forest Service. The research was prompted by an aggressive impoundment development effort on the Chippewa National Forest and a need to refine our knowledge of the best management practices for maximizing wildlife benefits and identifying adverse environmental effects. In the latter case, we were most concerned about the effects on the quality of downstream waters. In preparing a problem analysis and in conducting the research, it became apparent that a diverse array of impoundments were common throughout the western Great Lakes region and that various federal and State agencies, counties and private organizations were actively involved in building and managing them for wildlife. The need for a regional workshop focusing on impoundments was obvious. Therefore, we scheduled a workshop to coincide with the conclusion of the North Central Forest Experiment Station's impoundment research program. The workshop, sponsored by the North Central Forest Experiment Station and the Chippewa National Forest, was held in late summer 1982, near Bemidji, Minnesota. There were over 85 attendees representing federal, state, county and private wildlife interests throughout the western Great Lakes region, including Canada.

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MANAGED WETLAND HABITATS FOR WILDLIFE: WHY ARE THEY IMPORTANT?

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Wetland habitats provide life necessities for a myriad of wildlife. Many species not normally associated with wetlands also acquire important nutrients or use the cover available in wetlands during some phase of their annual cycle. The most obvious requirement that wetlands provide wildlife is the available food for reproduction, growth, and survival. Currently we know more about how birds and mammals exploit wetlands than how fish, amphibians, reptiles, and invertebrates do. I will use birds as primary examples in this paper because their nutritional and habitat requirements are more thoroughly understood than for any other vertebrates.

New evidence with birds provides a clearer understanding of the many relations among the resources available from wetlands at different latitudes and the adaptations that allow migrants to acquire life necessities. Weller (1975) has suggested how wetlands at different latitudes provide the resources required by waterfowl at different periods in the annual cycle. Dabbling ducks use freshwater wetlands and consume more invertebrates during the reproductive period in southern Canadian provinces but migrate to southern inland and coastal wetlands and consume a larger proportion of plant materials in fall and winter.

The potential for reproduction or survival of some migratory species may be strongly influenced by the conditions encountered within different wetland types at different latitudes or areas. For example, the reproductive success of the purple heron (*Ardea purpurea*) in the Netherlands is closely related to the winter wetland conditions of the Senegal and Niger river deltas in western Africa (den Held 1981). Likewise, the availability of high quality winter wetland habitat within the Mississippi Alluvial Valley is closely correlated with the reproductive success of mallards (*Anas platyrhynchose*) in North America (Heitmeyer and Fredrickson 1981). These recent findings complicate management of local or region wetland complexes because response by some target species may be controlled, in part, by conditions well outside a management area. These findings also demonstrate that we need to know the life histories and requirements of species we want to manage. We also need to know the role of local wetlands in providing specific requirements at important periods in the annual cycle.

The greatest potential for developing impoundments is in regions where former wetland watersheds have been modified by agriculture, or in areas of undulating topography where riparian lands are abundant. However, modifying natural wetlands by impoundments may result in radically different hydrologic regimes that are not ecologically sound. For example, waterfowl select natural wetlands over impounded water such as farm ponds in Oklahoma (Heitmeyer and Vohs 1981). Impoundment of streams in the North Central forested region can be either beneficial or detrimental depending on the watershed, the species involved, and the specific habitats lost or gained. The goal of this paper is to summarize the importance of man-made or natural wetlands for wildlife and to suggest ways to manipulate man-made or man-altered habitats to meet the life necessities of wildlife.

WETLAND HABITAT LOSSES AND DEGRADATION

Wetland losses have an obvious impact on wildlife but the results of wetland degradation on wildlife populations are also serious. Even though individual wetland basins may remain intact and hold water, their productivity may change so dramatically that resources required for wildlife are reduced or no longer available.

The lack of baseline data on the original area, quality, and distribution of different wetland types in North America precludes an accurate appraisal of cur-

rent wetland losses and degradation. But losses within the prairie pothole region of the north central United States have been estimated at 51 percent between 1900 and 1955 (Schrader 1955) and 75 percent between 1850 and 1977 (U.S. Department of Agriculture 1980). In Iowa where agriculture has been highly developed, at least 95 percent of the original natural wetlands have been lost (Bishop 1981).

Minimal losses of waterbird production through complete drainage and conversion, partial drainage, and flooding of Type IV prairie potholes have been estimated to exceed 90 million nests (Weller 1981a). Awesome habitat losses and decreased productivity face the prairie wetland manager whose role is to maintain habitat and wildlife for a growing demand by consumptive and nonconsumptive users.

Because wetlands in the northern prairies are used by waterbirds for nesting and brood rearing, losses of these northern wetlands have high public visibility. Losses of wetlands used during the migratory and wintering phases of life cycles are more obscure. Most migratory birds are more social during the nonbreeding period and often form large aggregations. When aggregations utilize habitats where they are readily visible, they can mask the actual status of a continental population or give the impression that certain habitats play a more important role than they do. The importance of wetland complexes cannot be overstated. Each species requires many different resources throughout its life cycle and any individual wetland is unlikely to meet all of these needs.

Losses and degradation of winter wetlands are no less severe than on breeding areas. In Missouri lowland hardwood wetlands decreased by 96 percent from 1 million ha to less than 40,000 ha between 1870 and 1976 (Korte and Fredrickson 1977). More importantly, of the remaining area only about 5,500 ha function as the original ecosystem once did because forested tracts have been drained or isolated as tracts less than 100 ha in size. Similar losses have occurred throughout the Mississippi Alluvial Valley. Recent estimates indicate that less than 2 million ha of the original 10 million ha remain (MacDonald *et al.* 1979).Not only have areas been greatly reduced but nearly all sites in the Mississippi Alluvial Valley are subjected to adverse impacts such as turbidity, pollutants, and excess runoff that degrade the remaining wetland habitats (Fredrickson 1980a, Schmitt and Winger 1980). Managers face major challenges to provide adequate high quality winter wetland habitats for wildlife in the Mississippi Alluvial Valley because only 293,000 ha are held in public ownership (Fredrickson 1980a).

Losses and modifications of Gulf Coast wetlands also have been severe. Coastal wetland losses have reached 10,000 ha/yr in Louisiana alone (Galiano 1981). Mississippi River channel modifications have reduced or altered river delta formation because silt is transported and carried directly to the continental shelf in the Gulf of Mexico rather than being dropped in near-shore areas. Wetland degradation is also extensive. Channels dug for oil and gas exploration have allowed salt water to intrude from the Gulf Coast into marsh areas. Increasing salinities have reduced freshwater marsh habitat by 90 percent. Heavy urban and industrial use of freshwater from wells in coastal areas has increased salinities in some areas as well. As salinities increase, waterfowl use has dropped precipitously.

Degradation of wetland habitats comes in a variety of forms. We generally think of degradation as resulting from developing of agriculture, industry, mining, the military, transportation, urbanization or flood control. Thousands of potholes have been bisected by roads. Silt laden runoff from fields, roadbeds, construction sites, or mines, increase turbidity and fill wetland basins (Fredrickson 190a, Bellrose *et al.* 1979 Weller 1981a). Untreated sewage from feedlots and urban areas cause eutrophication that can enrich or degrade an area for wildlife use (Starret 1971, Swanson 1977). Enriched systems may shift algal and invertebrate communities to less desirable forms that are less advantageous to invertebrate predators or cause increased BOD and resulting fish or invertebrate die-offs, or both. Pollutants from agriculture or industry cause die-offs, reduce wildlife survival and reproduction, or make wild game unfit for human consumption (Baskett 1975, Krapu *et al.* 1973). Channel modifications for flood control and transportation often change the composition of vegetation outside project areas (Fredrickson 1979a, 1980b).

Managers also must realize that manipulating a wetland to enhance a certain habitat or to attract a certain species, may degrade it over the longer term. Managed wetlands often lack the seasonal and long-term water fluctuations that revitalize the system and maintain high productivity. The lack of precise water control, political or public pressure, inadequate or incorrect management information, climatic conditions, beavers, or conflicting management goals are but a few obstacles to successful management. Some wetlands have been flooded for recreation (Errington 1963), whereas others are used as a source of water for irrigation (Bolen 1982). Stabilized water levels reduce productivity and may result in vegetation-choked or alternately vegetation-free basins that are not attractive to nesting birds (Weller and Fredrickson 1974). Deeply flooded basins often lack emergent vegetation or only contain the most water-tolerant forms.

In southern forested wetlands some changes related to management practices are so subtle that 20 or more years may pass before degradation is obvious (Fredrickson 1979a, 1980a). Green-tree reservoir management is a common practice where levees are built around oak flats. When flooded during the dormant season, these areas provide mast and other native foods for ducks. Typically such managed forests are flooded earlier and deeper than would occur naturally. After many years of such management, reproduction of desirable food producing trees is nil. Mast production is reduced and mast producing trees suffer increasing mortality (Black, personal communication). During the early years of managed flooding these sites are of great value for wood ducks (*Aix sponsa*) and mallards, but after flooding degrades the habitat, the forest cannot be revitalized or replaced quickly to provide the habitat or foods normally utilized by these species in fall and winter.

WETLAND DYNAMICS

The abundance and distribution of plants and animals associated with wetlands are controlled by soil nutrients, climate, the quality and quantity of water, hydroperiod, and hydrological regime (Fredrickson 1982). The hydroperiod or seasonal and long-term availability of water is undoubtedly the single most important factor that influences habitat conditions and the subsequent use by wildlife (Carter *et al.* 1979). Seasonal and long-term changes in water conditions are well known on the prairie breeding grounds. More wetland basins are flooded and water depth is usually greater in spring than in summer or fall. Only the deepest basins may be filled in dry years but all or nearly all basins are filled in the wet years.

Natural wetlands are dynamic systems with constantly changing water conditions that influence the availability of nutrients for wildlife. Wetlands regularly occur as complexes where basins with different sizes and depths have plants with varying life-forms (Weller 1979, 1981b; van der Valk and Davis 1979). Each wetland type may provide habitat or nutrient resources for different groups of wildlife or provide different requirements for a single species during the annual cycle. Wetland complexes are no less important in southern regions when different habitats in close proximity to one another provide escape cover or nutrients for molt, migration, survival, fitness for reproduction, and other life history requirements (Fredrickson 1979a, 1980a; Heitmeyer and Fredrickson 1981). Southern wetlands are generally associated with riverine or coastal systems and different wetland types usually occur along a continuum rather than as discrete wetland basins (Bedinger 1979).

Regional patterns of southern inland wetland dynamics are demonstrated in Oklahoma (Heitmeyer and Vohs 1981). The seasonal and long-term patterns of precipitation determine the dynamics of Oklahoma wetlands. Seasonally the numbers of flooded basins are lowest in fall and early winter and basin numbers continue to increase in late winter and throughout spring and reach a peak in early summer. Fluctuations in the number of basins increases or decreases depending on the seasonal and long-term changes in rainfall locally and regionally. Peak number of wetlands did not occur in each of six physiographic provinces of Oklahoma during the same year or season (Heitmeyer and Vohs 1981). The degree of change between low and high water conditions within the same province during 1978-1980 indicated increases in basin numbers from 24 to 146 percent and increases in surface area from 89 to 324 percent. A similar degree of change occurred between numbers of May and July ponds in the prairie provinces of Canada (Strata 25-40) from 1955 to 1979 (U.S. Fish and Wildlife Service unpublished data). Such differences in regional dynamics of wetlands influence wildlife use and may explain different patterns of seasonal migratory movements.

Productivity (kg/m^2) of biomass in southern swamp forests is related to type of flooding regime (Odum 1979). Stagnant water or prolonged flooding results in the lowest productivity whereas peak productivity occurs on sites with seasonal flooding. Likewise, tidal fresh wetlands that occur in the upper reaches of riverine estuaries are among the most productive wetlands because vegetation benefits from moderate tidal energy but plants are subjected to less stress from salt or storm tides (Whigham *et al.* 1978).

The consistent relations between productivity and water dynamics regardless of wetland type or latitude clearly indicates that effective and well-timed water manipulations are of central importance to wetland management. If managed areas are to provide essential wildlife habitat when total wetland area is decreasing and the remaining wetland area is subjected to further degradation, manipulations should (1) shorten long-term water cycles, (2) provide essential habitat both in and out of phase with natural complex cycles, (3) prevent stabilization of water levels, and (4) make food available during critical periods in the annual cycle.

REQUIREMENTS FOR ENERGY AND COVER

The adaptations of species that utilize wetlands have been shaped by the availability and distribution

of energy within wetland systems. For simplicity, the term energy will be used in its broadest context to include other nutrients as well as energy. The constantly changing availability of energy during the year provides proximate cues that control the timing of events in the annual cycle of plants and animals. The irregular fluxes in energy related to the long-term changes in the hydroperiod ultimately control morphological and other adaptations required for reproduction and survival. The availability of energy enables animals to exploit these wetland habitats as they reproduce and grow and thus ensures their survival.

The availability of energy in wetlands is ultimately related to the supply and internal cycling of nitrogen and phosphorus in the system (Kadlec 1979). Nutrients are available internally from sediments, water, and from decomposition processes. Wetlands also receive important inputs from the surrounding watersheds (Davis *et al.* 1981, van der Valk *et al.* 1979). Controlling these nutrients requires careful attention to water regulation because the mobility of phosphorus and denitrification processes are related to rapid and frequent water level fluctuations.

Reproduction, growth, and survival of wildlife are possible only if adequate energy is available in each of the wetland types used during the annual cycle or if energy can be transported among wetland systems. Our current level of research has provided a baseline understanding of changes in weights and body composition of waterfowl during reproduction and to other energy-demanding periods of the annual cycle. Identification of energy requirements is critical to the development of management options but understanding and conditions that make resources available within wetland systems is no less important for effective management. Managed systems are most valuable when they continue to provide wildlife with energy above maintenance levels during critical periods in the annual cycle as well as over a series of years.

Changes in the seasonal availability of energy are most obvious at high latitudes where ice cover makes energy unavailable. Aquatic foods are locked within frozen wetlands and food production processes are slowed or cease. Most northern hemisphere vertebrates that use high latitude wetlands migrate to milder climates where energy is more readily available during their nonbreeding season. Special adaptations allow some species to nest in high latitudes. Arctic nesting snow geese (*Anser caerulescens*), Canada geese, and black brant (*Branta bernicla*) carry energy from more southern wintering and migration areas to the breeding grounds (Ankney and MacInnes 1978; Raveling 1978, 1979). These body reserves enable geese to lay eggs before food is readily available locally on the breeding areas. The early timing of laying allows eggs to hatch at a time when food resources will be in abundance for developing offspring. The availability of sunlight for long periods daily allows young to develop rapidly during the short arctic summer when wetlands are ice free. Use of resources by wildlife at different latitudes indicates that wetlands should be viewed along a continuum. Even though resource use may occur during a short period in the annual cycle at a given location, the resources acquired may be critical to many birds such as migratory geese that nest or winter elsewhere.

Concentrations of waterbirds are suggestive of pulses of readily available energy resources within wetlands or on adjacent uplands. Peak numbers of diving ducks exceeded 0.5 million birds on the Mississippi River at Pool 19 near Nauvoo, Illinois in the 1960's (Thompson 1973). Plant resources were few but the birds readily exploited a large population (over 100,000/m^2 of fingernail clams (*Sphaerium transversum*) In Missouri, grackles (*Quiscalus quiscula*) and killdeer (*Charadrius vociferus*) concentrated on a seasonally flooded impoundment to exploit a physid snail population that was vulnerable to predation during a drawdown (Reid 1983). Ninety-six percent of the isolated snail population was consumed in a few days.

In many cases foods are closely associated with aquatic plant communities. Canvasbacks (*Aythya valisineria*) concentrated near beds of *Potamogeton pectinatus* and *P. richardsoni*, whereas redheads (*Aythya americana*) concentrated near scattered beds of *Scirpus acutus* and where *P. pectinatus, Ruppia occidentalis,* and *Chara* sp. predominated in a large southern boreal lake in the late summer molting period (Bergman 1973).

Although we often think of plants as providing energy directly in the form of seeds and leafy material, they also may serve as important substrates for invertebrates. Voigts (1976) has shown the importance of vegetation substrates for invertebrates in glacial marshes. Birds that concentrate on sites with plants lacking food value in seasonally flooded impoundments in Missouri probably are exploiting invertebrates (Taylor 1978, Fredrickson and Taylor 1982, Reid 1983 unpublished).

Foods are of primary importance but life cycles cannot be completed without adequate cover. Successful nesting requires vegetation with the desired vertical and horizontal structures. Glacial emergent wetlands of the upper Midwest have seasonal changes in area and interspersion of cover and water (Weller and Spatcher 1965, Weller and Fredrickson 1974, Weller 1981b). Vegetation changes are related to change in

water levels and to muskrat populations. Ideal cover conditions that support rich bird faunas with maximum numbers of individuals occur when vegetation is patchy and the ratio between cover and water is about 50:50 (Weller and Fredrickson 1974). Number of taxa, biomass, and density of invertebrates increased dramatically 4 weeks after cattails (*Typha latifolia*) were cut and removed from plots in southern Manitoba (Murkin *et al.* 1982). Feeding by waterfowl had a higher frequency on the plots once invertebrate biomass increased and the best use was associated with a 50:50 water-cover ratio (Kaminski and Prince 1981).

Shorebirds generally are associated with unvegetated or sparsely vegetated habitats but recent evidence suggests that common snipe (*Capella gallinago*) forage in wet habitats with more robust upright cover during midday (Rundle 1981). In contrast to inland migrant shorebirds, rails center their activities on sites with robust upright vegetation and shallow water (Rundle and Fredrickson 1981). Maintaining upright vegetation is relatively easy in fall but by spring most upright vegetation has deteriorated because of flooding, heavy wildlife use, muskrat eat outs, or weather.

An understanding of the fluctuations in body lipids and proteins during the annual cycle is important in formulating management practices. Sophisticated technology is available to monitor fatty acids and amino acids of foods as well as their content within wildlife. A more complete understanding of the availability of imortant amino and fatty acids and how they are utilized by wildlife will enhance our abilities to provide maximum benefits to wildlife. Increasingly effective and precise management of wetland habitat is essential as wetland areas continue to decrease in size and quality.

IMPOUNDMENTS AND WILDLIFE: MANAGEMENT POTENTIAL

Wetland impoundments for wildlife can be classified in a variety of ways. Some impoundments were designed and constructed for wildlife whereas others are used by wildlife but were constructed or resulted from some other purpose. Highway barrow areas, stock ponds, and cooling reservoirs for power plants provide a few examples of impoundments built for purposes other than wildlife. Their value is often reduced because of location, size, and conflicting uses (Ruwaldt *et al.* 1979, Lokemoen 1973, Oetting and Cassel 1971, Anderson 1978). Impoundments specifically developed for wildlife are either modifications of natural wetland basins or are designed and constructed for wildlife on sites where wetlands are non-existent.

Management potential is usually best on sites developed specifically for wildlife but nearly any man-made wetland site has some management potential. In Texas there are an estimated 500,000 stock ponds with a surface area of 1 ha or less (U.S. Department of Agriculture 1980). These small ponds and larger impoundments of 1 ha or more account for over 1.5 million ha of surface water. Areas of such magnitude can provide potential habitat for a number of wildlife on a statewide basis. Nevertheless, management problems associated with water availability, (excess or insufficient), water control, disturbance, or regional politics, often reduce potential use on areas whether or not they were designed specifically for wildlife.

Where hydroperiods can be manipulated, managers have opportunities to duplicate natural water fluctuations or to provide important habitats out-of-phase with natural hydroperiods. Experimentation in Iowa indicated the bird response to habitat conditions provided on a managed Type IV glacial wetland was excellent during a regional drought when surrounding natural wetlands had reduced bird use (Weller and Fredrickson 1974). Manipulation of single wetland basins can never duplicate the quality of dynamics of natural wetland systems. Nevertheless, management of groups of man-made or man-modified wetland basins can more closely duplicate the habitats available in natural systems. For example, in southeastern Missouri, groups of seasonally flooded impoundments are manipulated regularly to attract and hold a diverse wildlife fauna including over 140 species of birds and especially waterflowl, herons, rails, and shorebirds, as well as mammals, amphibians, and reptiles (Rundle and Fredrickson 1981, Fredrickson and Taylor 1982). Although wetland use by a variety of wildlife may remain high, shifts in the composition of wildlife that respond to managed conditions should be expected. When management is targeted for shorebirds rather than ducks, waterfowl numbers remain constant by the composition of waterfowl species that are attracted to the management area may change and favor those that use shallow water and mudflats, such as Canada geese (*Branta canadensis*) and pintails (*Anas acuta*) (Rundle and Fredrickson 1981).

In most cases the value of management has been measured by either increases in numbers or in species richness. Habitat changes resulting from wetland management might only make birds more visible or attract certain abundant species. Habitat needs for other species with critical habitat may no longer be met or entire riparian zones or certain water depths might be lacking after developments. Better methodology in monitoring changes resulting from impoundment development are critical to refining management procedures.

Impoundments at northern locations are often managed for breeding birds. Providing food resources comes first but nesting cover must be present as well. Management of impoundments in the south is often centered on providing food resources for migrant and wintering birds. Wildlife response to drawdowns in Missouri suggest that diverse wildlife use is possible when manipulations are well timed. Early in the season deeper waters (greater than 25 cm) supply migrants such as grebes, coots, and diving ducks with suitable habitats. Reducing the water level (25 to 5 cm) as spring progresses provides suitable foraging areas for later migrants such as shovelers (*Anas clypeata*) and blue-winged teals (*Anas discors*). Holding water levels between 5 and 25 cm provides extensive foraging area for herons. Reducing some areas to mudflats attracts shorebirds and raccoons (*Procyon lotor*) and eventually carrion feeders such as common crows (*Corvus brachyrhynchos*) and turkey vultures (*Cathartes aura*).

Management options for wetlands are many but most require a basic understanding of nutrient cycling, plant ecology, and animal population dynamics. Rapid changes within wetland systems dictate that conditions must be monitored continuously in managed basins. One final note of caution: the best management decision within a given location may be to maintain existing wetland basins as unmodified entities where natural forces are allowed to operate without interference from man. Wetland function is so complex that our management desires to meet requirements for a target species may preclude maintaining the basin as a dynamic productive wetland. Management efforts are best centered on habitats that are man-made or on natural habitats that were subjected to perturbations not associated with wildlife management. Only then can managers meet the responsibility to the resources and users alike.

Managers in the north central region have unique opportunities and responsibilities for providing wetland habitats in forested regions. The selection of impoundment sites, development to enhance the productivity of the forested ecosystem, and adequate pre- and post-impoundment monitoring provide many management challenges. Because wetlands are influenced by activities within their watersheds, on adjacent uplands, and even at distant locations, wetland management must be part of a more comprehensive management plan. Timber harvest sites and practices can influence runoff and sedimentation; high recreational demands, and the location of roads, camps and trails determine the level and location of disturbance; and distant power plants can influence water quality. Attention to the dynamics of wetlands and outside influences will assure that these managed wetlands will remain productive, benefit a rich wildlife fauna, and provide much public enjoyment at a reasonable cost. This workshop should be an important step in meeting these challenges.

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LITERATURE CITED

Anderson, W. L. Waterfowl collisions with powerlines at a coal-fired plant. Wildl. Soc. Bull. 6: 77-83; 1978.

Ankney, C. D.; MacInnes, C. D. Nutrient reserves and reproductive performance of female lesser snow geese. Auk 95: 459-471; 1978.

Baskett, T. S. Mercury residues in breast muscle of wild ducks, 1970-71. Pesticides Monitoring Journal 9: 67-78; 1975.

Bedinger, M. S. Relation between forest species and flooding. In: Greeson, P. E.; Clark, J. R.; Clark, J. E., eds. Wetland functions and values: the state of our understanding. Minneapolis, MN: Am. Water Resour. Assoc.; 1979; 427-435.

Bellrose, F. C.; Paveglio, F. L., Jr.; Steffeck, D. W. Waterfowl populations and the changing environment of the Illinois River Valley. Illinois Nat. Hist. Surv. Bull. 32(1): 11-54; 1979.

Bergman, R. D. Use of southern boreal lakes by postbreeding canvasbacks and redheads. J. Wildl. Manage. 37: 160-170; 1973.

Bishop, R. A. Iowa's wetlands. Proc, IA. Acad. Sci. 88: 11-16; 1981.

Bolen, E. G. Playa wetlands of the U.S. Southern High Plains; their wildlife values and challenges for management. In: Gopal, G.; Turner, R. E.; Wetzel, R. G.; Whigham, D. F., eds. Wetlands: Ecology and Management National Institute of Ecology and International Scientific Publications; 1982: 9-20.

Carter, V.; Bedinger, M. S.; Novitzki, R. P.; Wilen, W. O. Water resources and wetlands. In: Greeson, P. E.; Clark, J. R.; Clark, J. E., eds. Wetland functions and values: the state of our understanding. Minneapolis, MN: Am. Water Resour. Assoc.; 1979: 344-376.

Davis, C. B.; Baker, J. L.; van der Valk, A. G.; Beer, C. E. Prairie pothole marshes as traps for nitrogen and phosphorus in agriculture runoff. In: Richardon, B., ed. Selected proceedings of the Midwest Conference on Wetland Values and Management.

St. Paul, MN: Minnesota Water Planning Board; Water Resources Research Center, University of Minnesota; Upper Mississippi River Basin Commission; and Great Lakes Basin Commission; 1981: 153-163.

den Held, J. J. Population changes in the purple heron in relation to drought in the wintering area. Ardea 69: 185-191; 1981.

Errington, P. L. The pricelessness of untampererd nature. J. Wildl. Manage. 27: 313-320; 1963.

Fredrickson, L. H. Lowland hardwood wetlands: current status and habitat values for wildlife. In: Greeson, P. E.; Clark, J. R.; Clark, J. E. eds. Wetland functions and values: the state of our understanding. Minneapolis, MN: Am. Water Resour. Assoc.; 1979a: 296-306.

Fredrickson, L. H. Floral and faunal changes in lowland hardwood forests in Missouri resulting from channelization, drainage, and impoundment. U.S. Department of Interior; 1979b; FWS/OBS-78191; 130 p.

Fredrickson, L. H. Management of lowland hardwood wetlands for wildlife: problems and potential. Trans. No. Am. Wildl. Nat. Resour. Conf. 45: 376-386; 1980a.

Fredrickson, L. H. Impacts of water management on the resources of lowland hardwood forests. In: Chabreck, R. H.; Mills, R. H., eds. Integrating timber and wildlife management in southern forests: 19th Annual Forest Symposium; Baton Rouge, LA: Louisiana State University; 1980b: 51-64.

Fredrickson, L. H.; Taylor, T. S. Management of seasonally flooded impoundments for wildlife. Resour. Publ. 148. U. S. Department of the Interior, Fish and Wildlife Service; 1982. 29 p.

Gagliano, S. M. Special report on marsh deterioration and land loss in the Deltaic Plain of coastal Louisiana. Baton Rouge, LA: Coastal Environments, Inc.; 1981. 14 p.

Heitmeyer, M. E.; Fredrickson, L. H. Do wetland conditions in the Mississippi Delta influence mallard recruitment? Trans. No. Am Wildl. Nat Resour. Conf. 46: 44-57; 1981.

Heitmeyer, M. E.; Vohs, P. A. Environmental characteristics of Oklahoma wetlands. Environ. Ser. 5. Oklahoma State University, Art and Sciences Research, 1981. 143 p.

Kadlec, J. A. Nitrogen and phosphorus dynamics in inland fresh water wetlands. In: Bookhout, T. A., ed. Waterfowl and wetlands--an integrated review proc 1977. Madison, WI; North Central Section of the Wildlife Society; 1979: 17-42.

Kaminski, R. M.; Prince, H. H. Dabbling duck and aquatic invertebrate responses to manipulated wetland habitat. J. Wildl. Mange. 45: 1-15; 1981.

Korte, P. A.; Fredrickson, L. H. Loss of Missouri's lowland hardwood ecosystem. Trans. No. Am. Wildl. Nat. Resour. Conf. 42: 31-41; 1977.

Krapu, G. L.; Swanson, G. A.; Nelson H. K. Mercury residues in pintails breeding in North Dakota. J. Wildl. Manage. 37: 395-399; 1973.

Lokemoen, J. T. Waterfowl production on stock-watering ponds in the northern plains. J. Range Manage. 26: 179-184; 1973.

MacDonald, P. O.; Frayer, W. E.; Clauser, J. K. Documentation, chronology, and future projections of bottomland hardwood habitat losses in the lower Mississippi aluvial plain. Vol. I. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service; 1979. 133p.

Murkin, H. R.; Kaminski, R. M.; Titman, R. D. Responses by dabbling ducks and aquatic invertebrate to an experimentally manipulated cattail marsh. Can. J. Zool. 60: 2324-2332; 1982.

Odum, H. T. The value of wetlands: a hierarchical approach. In: Greeson, P. E.; Clark, J. R.; Clark, J. E., eds. Wetland functions and values: the state of our understanding. Minneapolis, MN: Am. Water Resour. Assoc; 1979: 16-25.

Oetting, R. B.; Cassell, J. F. Waterfowl nesting on interstate right-of-way in North Dakota. J. Wildl. Manage. 35: 774-781; 1971.

Raveling, D. G. The timing of egg laying by northern geese. Auk 95: 294-303; 1978.

Reveling, D. G. The annual energy cycle of the cackling goose. In: Jarvis, R. L.; Bartonek, J. C., eds. Management and biology of Pacific Flyway geese; 1979. Portland, OR: Oregon State University; 1979: 81-93.

Reid, F. A. Aquatic macroinvertebrate response to management of seasonally flooded wetlands. Columbia, MO: University of Missouri; 1983. 100 p. M. S. Thesis.

Rundle, W. D.; Fredrickson, L. H. Managing seasonally flooded impoundments for migrant rails and shorebirds. Wildl. Soc. Bull. 9: 80-87; 1981.

Ruwaldt, J. J.; Flake, L. D.; Gates, J. M. Waterfowl pair use of natural and manmade wetlands in South Dakota. J. Wildl. Manage. 43: 375-383; 1979.

Schmitt, C. J.; Winger, P. V. Factors controlling the fate of pesticides in rural watersheds of the lower Mississippi River alluvial valley. Trans. No. Am. Wildl. Nat. Resour. Conf. 45: 354-375; 1980.

Schrader, T. A. Waterfowl and the potholes of the North Central States. In: Yearbook of Agriculture, 1955. Washington, DC: U. S. Department of Agriculture; 1955: 596-604.

Starrett, W. C. A survey of the mussels (Unionacea) of the Illinois River: polluted stream. Ill. Nat. Hist. Surv. Bull. 30(5): 267-403; 1971.

Swanson, G. A. Diel food selection by Anatinae on a waste-stabilizaion system. J. Wildl. Manage. 41: 226-231; 1977.

Taylor, T. S. Spring foods of migaratory blue-winged teals on moist soil impoundments. J. Wildl. Manage. 42: 900-903; 1978.

Thompson, D. J. Feeding ecology of diving ducks on Keokuk pool, Mississippi River. J. Wildl. Manage. 37: 367-381; 1973.

van der Valk, A. G.; David, C. B.; A reconstruction of the recent vegetational history of a prairie glacial marsh, Eagle Lake, Iowa, from its seed bank. Aquat. Bot. 5: 29-51; 1979.

van der Valk, A. G.; Davis, C. B.; Baker, J. L.; Beer, C. E. Natural fresh water wetlands as nitrogen and phosphorus traps for land runoff. In: Greeson, P. E.; Clark, J. R.; Clark, J. E., eds. Wetland functions and values: the state of our understanding. Minneapolis, MN: Am. Water Resour. Assoc.; 1979: 457-467.

Voigts, D. K. Aquatic invertebrates abundance in relation to changing marsh vegetation. Am. Midl. Nat. 95: 312-322; 1976.

U. S. Department of Agriculture. Appraisal 1980. Soil and Water Resources Conservation Act. Washington, DC; 1980.

Weller, M. W.; Migratory waterfowl: a hemispheric perspective. Publicaciones Biologicas Instituto De Investigaciones Cientifiicas V.A.N.L. 1: 89-130; 1975.

Weller, M. W. Wetland habitats. In: Greeson, P. E.; Clark, J. R.; Clark, J. E., eds. Wetland functions and values: the state of our understanding. Minneapolis, MN: Am. Water Resour. Assoc.; 1979: 210-234.

Weller, M. W. Estimating wildlife and wetland losses due to drainage and other perturbations. In: Richardson, B., ed. Selected proceedings of the Midwest conference on wetland values and management. Minnesota Water Planning Board; Water Resources Research Center, University of Minnesota; Upper Mississippi River Basin Commission; and Great Lakes Basin Commission; 1981a: 337-346.

Weller, M. W. Freshwater marshes: ecology and wildlife management. University of Minnesota Press; 1981b. 146 p.

Weller, M. W.; Fredrickson, L. H. Avain ecology of a managed glacial marsh. Living Bird 12: 269-291; 1974.

Weller, M. W.; Spatcher, C. E. Role of habitat in the distribution and abundance of marsh birds. Spec. Dep. 43. Iowa State University Agriculture and Home Economics Experiment Station; 1965. 31 p.

Whigham, D. F.; McCormick, J.; Good, R. E.; Simpson, R. L. In: Good, R. E.; Whigham, D. F.; Simpson, R. L., eds. Freshwater wetlands, New York: Academic Press; 1978: 3-20.

WETLAND MANAGEMENT: PUBLIC CONCERN AND GOVERNMENT ACTION

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Public attitudes about wetlands are changing and we now have a better appreciation for wetlands and their values to the public. Despite substantial efforts made to protect wetlands, losses have been accelerating as a result of a combination of both natural and human activities.

STATUS OF WETLAND RESOURCE

The last U. S Fish and Wildlife inventory of wetlands in the U. S. (Circular 39, 1956) indicates that there were some 12.4 million acres in the north central area. Since 1954 (when the inventory was made), some areas have lost substantial amounts of wetlands while others have not changed significantly. Iowa, Illinois, and Missouri have lost at least 25 percent of their wetlands in the past 20 years. In Michigan, Minnesota, and Wisconsin, 5 to 10 percent have been lost in the past 20 years.

Wetland drainage in the prairie pothole region is occurring at the rate of 1 to 2 percent per year--some 15,000 to 20,000 acres per year in Minnesota, North Dakota, and South Dakota. About 2 million acres of wetlands remain in North Dakota of an original 4.5 million acres. By the year 2000 there will be a further loss estimated at 0.6 to 0.8 million acres. This is significant because North Dakota hosts some 40 percent of the breeding ducks in the lower 48 states. In Iowa, 97 percent of the wetlands have been drained.

Bottomland hardwoods have been cleared at an average of some 165,000 acres per year over the past 40 years. In the lower Mississippi Valley, bottomland hardwoods have declined from 12 million to 5.2 million acres. With current trends only 3.9 million acres will remain by 1995.

This loss has not only affected the 2.5 million waterfowl hunters, but the commercial fishery, the furbearer harvest, habitat for endangered, threatened, and non-game species, the hardwood timber resource, and has reduced natural flood retention. The fish and wildlife service has stated that, "There is no indication that the ongoing alteration of wetlands will cease or be reduced in the near future."

A major share of the wetlands are being drained as a result of agricultural and other development. The rich bottomland soils are extremely productive and bring a higher rate of return when planted than if left in wetlands or managed for hardwood timber. Annual returns for managed hardwoods are less than half the return that can be realized for corn or soybeans.

Losses of wetlands have taken their toll on fish and wildlife. Breeding mallard populations, after some 20 years of relative stability, are declining at an average rate of about 3 percent per year. Incentives to drain marginally unproductive wetlands increase as the cost of land and prices for agricultural products increase, and as technology improves.

WETLAND VALUES

Productivity.--Wetlands are among the most productive ecosystems. They support a wide diversity of aquatic and terrestrial life; studies in salt marshes show production of 10 tons of organic material per acre per year--a yield that exceeds the most fertile agricultural lands. From 70 to 90 percent of the commercially important fish and shellfish depend upon coastal marshes.

Water Quality.--Wetlands act as nutrient traps and control sediment. In 1981, 96 wastewater treatment facilities in the Lake States were utilizing wetlands, principally cattail marshes. Tertiary treatment benefits at one plant were estimated at $80,000 per year. The Forest Service has a test treatment plant in cooperation with the State and City of Drummond, Wisconsin.

Flood Control.--Wetlands provide a natural means of flood control by retaining water during periods of high runoff. Studies have shown that wetlands can

retain 50 to 80 percent of total runoff. A study of Wisconsin watersheds concluded that flood flows are 80 percent lower and sediment yields are 90 percent lower in basins consisting of 40 percent lake and wetland areas than in basins with no lakes or wetlands. Many of the State and national forests significantly reduce floods. The Corps of Engineers estimated that flood control benefits afforded by wetlands in the Charles River basin (Mass.) were worth $2,000 per acre per year.

Groundwater Recharge.--The Cedarburg Bog in Southern Wisconsin supplies water to suburban Milwaukee. The 5 square mile wetland controls groundwater supply for an area of about 165 square miles. A Massachusetts study showed that the value of one acre of wetland for groundwater recharge was $100,700.

Fish and Wildlife.--Wetlands provide habitat for all types of wildlife, those used consumptively as well as nonconsumptively. They provide critical habitat for some 80 of 276 species considered threatened and endangered. The 10 to 12 million ducks that breed annually in the lower 48 states are direct products of wetlands. Many species are dependent upon riparian habitat. Wetlands support over 40 percent of the nation's annual fur harvest. In 1975, 8.3 million Americans hunted migratory waterfowl, and spent $950 million for this wetland-dependent activity. Wetlands support a variety of fish and fishing use. In 1980, 36.4 million freshwater fishermen spent 710 million days and $7.8 billion pursuing their sport.

WETLAND REGULATIONS

Regulations currently affecting most States begin at the national level, run down to the State level, and through zoning ordinances, extend to the local level. In Wisconsin, for example, these include:

1. Section 404 of the Federal Clean Water Act (PL 95-217) which regulates the disposal of dredged materials, or the placement of fill into wetlands adjacent or contiguous to lakes, rivers, and streams, and includes other wetlands with special values. It is administered by the U. S. Army Corps of Engineers and the Environmental Protection Agency.

2. Section 10 of the River and Harbor Act of 1899 regulates any work in, over, or under navigable waters. It affects wetlands adjacent or contiguous to navigable waters. It is administered by the U. S. Army Corps of Engineers.

3. State statutes (e.g., Wisconsin Chapter 30 and 31) that regulate alteration of navigable waters involving wetlands contiguous to navigable waters and below the ordinary high water mark. These are administered by State DNR's.

4. Endangered species laws, such as the Federal Endangered Species Act, and state endangered species laws protect against the destruction of habitat, including wetlands, harboring endangered species. The Federal Endangered Species Act prohibits federal funding of actions which jeopardize the existence of endangered species. State statutes prohibit the taking, processing, or selling of endangered plants or animals.

5. Shoreline zoning, established under state statutes, such as the Water Resources Act of 1965 (Section 59.971) of the State of Wisconsin. This state law requires counties to enact shoreline regulations, including zoning provisions, land controls and enforcement. Under this statute, the Wisconsin DNR adopted a regulation (NR 115) to protect wetlands within shoreland areas of unincorporated areas. If the counties fail to adopt an ordinance, the DNR will adopt an ordinance for the counties.

6. Flood plain zoning, such as under Wisconsin Statutes (Section 87.30) requires flood plain zoning for areas where serious flood damage is probable. These laws regulate activities that might interfere with discharge of floodwaters or increase the extent of flood damage. They can be used to prevent conversion of wetlands for uses considered detrimental to the flood plain. Some urban development can be controlled. The legislation is intended to permit preservation of flood plain wetlands for their flood storage capacity. In Wisconsin this law is administered by the County Planning and Zoning Administrators.

7. Agricultural conservancy zoning--on the State and local level, regulates non-farm development in zoned areas and is adopted at county and town discretion. It protects wetlands, as well as farmlands, from conversion to other uses, and is chiefly designed to stop urban development. It is generally administered by the County.

STATE LAWS

Wisconsin.--Various attempts have been made to enact legislation to protect Wisconsin's wetlands. In 1977, legislation was passed requiring the Department of Natural Resources to prepare maps showing all wetlands in the State which were 5 acres or more in size. This was referred to as the Mapping Bill.

Michigan.--Michigan passed a Wetlands Bill (Act No. 203) in January 1980. Starting in October, 1980, certain activities in specified wetland areas required a permit from the Michigan DNR. This included wetlands contiguous to lakes, rivers or streams, as well as wetland areas of 5 acres or more in 17 counties of over 100,000 population. Other counties and areas would come under permit requirements when a wetland in-

ventory was complete, unless the wetland areas were designated "essential." Michigan's law exempts farming, silviculture, and harvesting of crops, including timber.

Minnesota.--Minnesota has a wetlands permit program, called Minnesota Public Waters and Wetlands Permit Program. The program applies to types 3, 4, and 5 wetlands (Circular 39) and covers projects involving damage, filling, dredging, channelizing, culverts, etc. Permits are not required for beach sand riprap, boat launching ramps, or seasonal docks if certain conditions are met.

WETLAND LEGISLATION

Legislation protecting wetlands has not been successful for several reasons. The most significant include the following:

Poor Definition of Wetlands.--Definitions have ranged from those based on the Fish and Wildlife Service Classification (Circular 39) to those areas commonly called marshes, swamps, bogs or wet meadows, or "poorly drained" soils where aquatic vegetation is dominant. Agricultural interests have resisted these definitions as ambiguous. A rather precise definition of wetlands is necessary to describe the areas for which protection is intended.

Method of Regulation.--Various interest groups have advocated control at the local level while other groups have been proponents of State (DNR) control. Various legislative bills (ex. Wis. AB 604, AB 92, SB 320) have proposed a permit system, while others (AB 515 and AB 555) proposed a "restrictive order" approach, which could be initiated by a signed petition. Tax breaks, easements, purchase or private wetlands, and court actions to determine a "taking of property" have been used to compensate landowners for protecting wetlands. Often these differences have served to keep individual groups in disagreement, making wetland legislation difficult to enact.

Exemptions.--Legislation has often contained language so restrictive that most uses would have been prohibited unless a permit were obtained. Special interest groups have lobbied and written specific exemptions into the bills. As more exemptions are added, wetland preservation groups withdraw their support.

Other.--Other factors affecting enactment of wetland legislation include size of regulated wetlands, buffer zones surrounding the wetlands, required restoration of wetland areas unlawfully "altered," inconsistencies between nonexempted and exempted activities, and permit procedures.

Wetland legislation can best be enacted and enforced where a designation procedure for defining the wetland areas and requirements for use are set forth. In this way, an application for use can be measured against established standards. Prior studies and designation provide a basis for distinguishing the amount of protection necessary. A critical wetland could be set aside from all use while some areas might be subject to limited protection. A Department of Interior study recommends that enabling statutes define wetlands with "considerable specificity." This is necessary to provide precise legal criteria for mapping wetlands and to determine whether particular lands and development sites are in or out of regulatory boundaries.

Wetlands legislation, to be enacted, must ensure:

1. That prior regulations and controls be coordinated to avoid overlapping jurisdiction and confusion.
2. That land-use regulations such as control of wetland use provide for local input and planning.
3. That regulations recognize the physical variation of land or ecotypes over a geographical area.
4. That the impacts on social-economic patterns of local areas be considered in any regulation.

Wetland Classification

Opposition to wetland legislation has often involved the definition of wetlands. Proponents of legislation may clearly visualize the types of wetlands they desire to protect; however, landowners, agriculturists, and others foresee broader interpretations which might result in restrictions being applied to lands not originally intended. The definition of a wetland is difficult because of the diversity, and lack of a clear line between "wet" and "dry" lands. However, it is important that a universally accepted classification of wetland be adopted so that public and private groups can understand and support wetland protection efforts.

Circular 39, based on the 1954 inventory, provided a good basis for initial surveys of wetlands. Much of the legislation passed by Congress to date refers to wetland types defined by Circular 39. However, Circular 39 is now considered inadequate. Recognizing this, the Fish and Wildlife Service initiated a National Wetland Project (1975-79) to devise a wetland classification system that could be applied consistently on a national basis. This effort resulted in the new classification system defining wetlands as "land where the water table is at, near, or above the land surface long enough to promote the formation of hydric soils or to support the growth of hydrophytes." Many groups consider this definition too broad, and its use, *without qualifications*, in passing regulatory legislation, could

lead to public controversy. Agricultural interests, for example, view this with concern, because lands defined as wetlands may be farmed during dry periods. However, it is the classification of specific wetland types, rather than the broad definition of a "wetlands" that is used to regulate and protect public wetlands. For example, Minnesota's DNR, under their permit program, follow the guidelines found in Circular 39 to define wetlands that are regulated and protected under Minnesota law. These wetlands, "include and are limited to all types 3, 4, and 5 wetlands that have been designated as 'public waters,' which are 10 or more acres in size in unincorporated areas, or 2½ or more acres in size in incorporated areas."

National Wetlands Inventory

National Wetlands Inventory (NWI) has classified and mapped wetlands throughout 24 percent (715,000 square miles) of the lower 48 States and 3 percent of Alaska. In the "lower 48" these maps cover the coastal areas, Great Lakes, and the major river systems. As of April 1982, the Fish and Wildlife Service distributed over 125,000 copies of available maps. These wetland maps serve as a planning aid to development interests as well as local state and federal agencies. The Corps of Engineers also use the maps as an aid in administering the regulatory program since the waters and wetlands under the Corps; jurisdiction are part of the wetlands mapped by the Service. This wetlands inventory will provide a trend analysis to document changes in our Nation's wetlands over the past 20 years. These maps are also used in the administration of the Fish and Wildlife Coordination Act. This analysis is scheduled to be completed late this year.

CURRENT PUBLIC CONCERNS

Wetlands Protection Under "404"

Legislation (5.777, H.R. 393, H.R. 3083, and H.R. 3962) has been introduced that would dissolve major wetland protection efforts that regulate dredge and fill activities. The proposed legislation would remove wetlands from 404 protection and restrict federal jurisdiction over dredged and fill material to "navigable waters." The Bills would prohibit any federal agency from preventing disposals in non-navigable waters regardless of requirements under other Acts.

The Corps of Engineers' dredge and fill program is derived from section 404 of the Federal Water Pollution Control Act. It requires that a permit be obtained for certain discharges of dredged or fill material into the nation's waters, including wetlands and streams important to fish and wildlife. The permit program is under review by the Presidential Task Force on Regulatory Relief. The Corps, however, has maintained that the permit program is working, and its benefits outweigh its costs, and that concerns about permit time requirements can be resolved.

The Wildlife Management Institute reports that both the Fish and Wildlife Service and the National Marine Fisheries Service have been blamed for lengthy delays in reviewing permit applications. From July 1 to December 30, 1980, the Fish and Wildlife Service reviewed 6,376 applications. It regulates governing dredge and fill material. However, most States do not have adequate review procedures.

This is a critical year for wetlands protection. Congress must reauthorize the Federal Water Pollution Control Act before October 1, 1982, or funds will no longer be available to run the 404 program. When the act is opened for reauthorization, amendments to the Bill weakening section 404 may be added. There is considerable public support for not weakening the Act.

Wetlands Loan Act

In May 1982 the House Subcommittee on Fisheries and Wildlife Conservation and the Environment held oversight hearings to discuss ideas for bolstering protection of the nation's wetlands. Included were legislation to extend the Wetlands Loan Act until October 1, 1988. To date, about $145 million of the $200 million loan has been appropriated. Authority for the program expires in October 1982, and legislation must be enacted to extend the program, or 75 percent of the duck stamp income will be diverted from wetlands acquisition for the next decade to repay the loan.

The Fish and Wildlife Service has stated that an additional 1.7 million acres of wetlands is needed to maintain waterfowl and other bird populations. Proposals for generating funds to purchase these lands include:

1. Give federal tax benefits to landowners who sell wetlands to agencies that preserve the habitat (H.R. 6465).
2. Increase the $200 million Wetlands Loan Act ceiling.
3. Forgive the indebtedness incurred under the Wetlands Loan Act. This would relieve the duck stamp fund of pressure for repayment.
4. Increase the price of the current $7.50 duck stamp. (Currently, this provides about 40 cents more than the $1 duck stamp of the 1930's in terms of purchasing power).
5. Authorize a federal appropriation from general revenues to match duck stamp receipts until the wetland acquisition goal is achieved.

6. Require a duck stamp for persons entering a National Wildlife Refuge for any recreational purpose.
7. Amend the Federal Aid in Wildlife Restoration Act to require money taken under the administrative purposes authority of the Act to be used for wetland acquisition.
8. Amend the Federal Aid in Wildlife Restoration Act to require that funds reverting from States be used solely for wetlands acquisition.
9. Use some of the oil and gas royalties from refuges in Alaska--90 percent of the royalties now go to the State of Alaska, as compared to 50 percent in the lower 48 States.
10. Amend the Land and Water Conservation Fund Act to permit the money to be used to acquire habitat for migratory waterfowl. The Forest Service currently has authority under the LWCF Act to acquire lands for wildlife habitat, including wetlands habitat. This authority was included under amendments to the LWCF Act.

The Wildlife Managment Institute reports that with information from the hearings, legislation will be drafted during 1982 to help the Fish and Wildlife Service meet its wetland protection goals.

NATIONAL WATERFOWL PLAN

A National Waterfowl Management Plan for the United States was issued by the Fish and Wildlife Service in March 1982. The plan defines what is intended to be achieved by cooperatively managing waterfowl in the United States. It provides a basis for developing detailed flyway management plans. The plan identifies three major objectives that must be achieved to reach the goal of maintaining waterfowl populations for the benefit of people. These are:

- Protect and manage the habitat needed to maintain or increase waterfowl numbers.
- Achieve optimum waterfowl population levels consistent with the availability of habitat.
- Provide optimum opportunity for people to use and enjoy waterfowl.

This document sets forth a national goal for waterfowl in the United States. It provides guidance for the U.S. Fish and Wildlife Service, the States, and the other public and private agencies and organizations that work cooperatively in the conservation and management of these birds. It provides a basis for developing detailed management plans for each of the four waterfowl flyways, and contributes to the eventual development of an international North American waterfowl management plan.

The plan is organized around three major topics that encompass most waterfowl management issues: habitat, populations, and utilization. It identifies what needs to be done for waterfowl and how work will be accomplished.

U.S. Fish and Wildlife Service Programs

Fish and Wildlife Service programs undertaken to minimize wetland losses include:

Land Acquisition.--Traditionally, land acquisition has been the primary tool used by the Fish and Wildlife Service to conserve wetland habitat. Funding is derived from several sources, including the Land and Water Conservation Fund (LWCF), receipts from the tax on motor boat fuel, the sale of surplus property, and acquisition through other federal agencies such as the Corps of Engineers. The primary source of funding comes from the Migratory Bird Hunting and Conservation Stamps ("duck stamp"), supplemented by advance appropriations against future sales authorized by the Wetlands Loan Act of 1961. The "duck stamp" provides $15-16 million annually. The Wetlands Loan Act authorizes $200 million of added receipts, of which some $144 million has been authorized.

The goal of the Fish and Wildlife Service is to acquire habitat to support a duck population of 36.3 million. This would equal the population existing during the period 1955-1975. The primary emphasis will be on the conservation of waterfowl *production habitat.* A total of 12.5 million acres of waterfowl habitat will be needed to achieve this objective. The federal share was placed at 8 million acres, inlcluding the 3.5 million acres managed by the Fish and Wildlife Service. That leaves 4.5 million acres to be acquired at the federal level. The Service has purchased in fee or easement about 2.2 million acres toward this goal. Time is running out. Wetland acquisition has been decreasing in response to efforts to balance the federal budget. Fish and Wildlife Service realty personnel have been significantly affected by cuts in federal funding. State funding has also been reduced because of loss of cooperative funds from the Fish and Wildlife Service.

Fish and Wildlife Coordination Act.--The Coordination Act requires that federal water resource agencies give consideration to fish and wildlife in planning and implementing water resource development projects. The Service makes recommendations concerning the extent of possible losses to the fish and wildlife resources, as well as measures to prevent or mitigate losses. The Service also cooperates with state and federal agencies to develop or protect wetlands.

Clean Water Act--Sec. 404.--The Corps regulates the discharge of dredge and fill material into waters of the U.S. The Fish and Wildlife Service is provided an opportunity to review all projects and provide recommendations to the Corps concerning impacts on wildlife and fish. This program has been instrumental in preventing or minimizing losses to wetlands.

U.S.D.I. WETLANDS TASK FORCE

Interior Secretary Watt recently established a private sector task force to advise him on opportunities to protect wetlands. The task force consists of 24 members from industry, national conservation groups, sportsmen's organizations, and Congress. Secretary Watt and Alabama Governor Forrest James, co-chair the group.

The group is divided into five subcommittees to plan and implement wetlands protection strategy in the public and private sectors.

The Task Force will consider such subjects as:

- Ways of bolstering the national conservation effort.
- Private donations of interest in wetlands.
- An increase in the price of the Duck Stamp.
- Matching Duck Stamp receipts with Land and Water Conservation Fund Money.
- Offering landowners state and federal tax benefits to maintain wetlands.
- And other possibilities to improve the status of wetlands with and outside the U.S.

The task force will advise and counsel public and private officials on wetland protection. They will also develop a program to encourage landowners to donate wetlands or easements to state and federal agencies to protect wetlands.

In establishing the group, Watt noted that the federal wetlands protection program, begun in 1929, has not been as successful as would have been desirable, and a new initiative is needed for saving the wetlands from drainage.

SUMMARY

Although wetlands have received increased emphasis by resource agencies, the threats to wetlands are extensive and diverse. The wetlands that once covered 127 million acres in the lower 48 States now number about 80 million acres, and continue to disappear at the rate of 300,000 to 400,000 acres each year.

Interior Secretary Watt has directed the Fish and Wildlife Service to act more aggressively in the purchase of wetland areas which provide important migratory bird habitat using "duck stamp" receipts. Acquisition using other funds will be considered in light of budgetary constraints.

The Fish and Wildlife Service cannot do the job alone. The National Waterfowl Plan does not include opportunities to accomplish national objectives by other agencies. The Fish and Wildlife Service must solidify an active partnership with the other federal agencies, state and local governments, and private groups to achieve the Plan's objectives. Without a coordinated effort the long-term outlook for wetlands is not bright.

HISTORY OF WATER IMPOUNDMENTS IN WILDLIFE MANAGEMENT

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The 1920's and 1930's were times of change for natural resources in North America. It was beginning to become evident at this time that these resources were not unlimited. Unchecked habitat destruction and overexploitation were resulting in decreasing populations of wildlife. One of the most notable declines was experienced by waterfowl. Newspapers were even reporting declines in waterfowl harvest (e.g., "Poorest duck season on record", Grand Rapids Herald Review, 1931).

The first step in the solution of any problem is recognition. Vast areas of wetlands were drained, mostly for agricultural purposes, during the early decades of this century. One of the first discussions of this problem in a published public forum occurred in 1938 at the Third North American Wildlife Conference (Page *et al.* 1938). The Conservation Director of the Izaak Walton League questioned the justification for draining 84 million acres of wetlands, and called for adequate mitigation of habitat values lost as a result of water development and drainage. The following year Bourn and Cottam (1939) reported the first study that documented the effects on wildlife and plant associations of draining marshes. In their words " . . . the survival of one or all natural plant and animal associations on a marsh (following drainage) may be impossible."

However, the period also resulted in the development of professional wildlife management (Leopold 1933). Wildlife management evolved from the administration and regulation of harvests to the scientific management of populations and habitats. The advent of the Federal Aid in Wildlife Restoration Act (i.e., Pittman-Robertson Act) in 1937 provided much of the funding necessary to implement wildlife management practices needed to restore wildlife habitats, including marshes.

First to receive attention in the literature were the peatland marshes that had been drained to promote agriculture (Cox 1939, Dachnowski-Stokes 1939). These lands, at best, often produced only marginal crops and were always prone to fire. After these farming enterprises were abandoned, proposals were made to construct dams in these areas to impound water and restore wetland characteristics to the area. Many large wildlife managment areas came about in this fashion (Cartwright 1946, Nelson 1953, Penfound and Schneidau 1945). Following construction of water impoundment devices and subsequent restoration of water levels, it was felt that these restored wetlands would be most productive if water levels were maintained.

In the early 1940's managers continued to advocate stable water levels throughout the year in managed marshes to maximize waterfowl and furbearer production (Hewitt 1942, Zimmerman 1943). However, initial studies were also completed at this time on how naturally fluctuating water levels affect the vegetation and wildlife associated with wetlands (Bellrose and Brown 1941, Bellrose and Low 1943, Yeager and Anderson 1944). Investigators also began to recommend manipulation of water levels in natural marshes to increase waterfowl and muskrat productivity (Pirnie 1941) and to manipulate wetland habitats (Uhler 1944).

Productivity in many of the large marshes that were restored in the 1930's began to decrease in the 1940's (Hartman 1949), even though the restored marshes often showed higher productivity initially than the original marsh (Penfound and Schneidau 1945).

By the late 1940's it was apparent that most wildlife managers agreed that periodic drawdowns were necessary to maintain high productivity in natural and restored wetlands (Errington 1948, Griffith 1948).

Investigators also began to realize that natural wetlands may not always be highly productive and that impoundments may be constructed to create wetlands where they did not exist before or to enhance management of natural wetlands. Mendall (1949) called for construction of small scale water impoundments throughout " . . . the northern States and southern Canada, west to the Plains States and Prairie Provinces." Speake (1955) recommended the construction of small impoundments in the southeast in 1955. In fact, impoundments had already been built in the east and south that were being managed with periodic drawdowns (MacNamara 1948, and 1949, Penfound 1949, Truax and Gunther 1951).

Waterfowl censuses conducted in 1947 and 1948 indicated that the long downward trend in the continental waterfowl population had been stopped (Mendall 1949). Large-scale draining of marshes had been slowed; drained wetlands had been restored; and intensive scientific management of wetlands for wildlife production had been initiated. All contributed to stem the decline of waterfowl populations.

In the late 1940's and early 1950's the use of small impoundments as a wildlife management technique gained wide acceptance. Use of water impoundment techniques raised many questions about the ecological processes and consequences of constructing and managing impoundments. However, the first study reported in the literature that addressed the ecological relations of water impoundment involved beaver dams and their effect on trees (Wilde *et al.* 1950). The results indicated that ferrous iron accumulated in impoundment soils, which led to the fixation of phosphorus in a insoluble form. The authors further stated, " . . . the impoverishment of soil in available nutrients and its enrichment in growth-inhibiting substances are characteristic of flowage bottoms . . ." forming a basis for understanding why productivity declines in impoundments after several years.

The program to develop small, artificial marshes in New York State exemplifies the efforts of public agencies to improve and expand wetland habitats through impoundment techniques. New York State developed --with the aid of the Fish and Wildlife Service and the Soil Conservation Service--specific criteria used to evaluate potential impoundment sites (Bradley and Cook 1951). Impoundment construction began under this program in 1949. Impoundments were constructed on private land, on a cost-sharing basis, through local Soil Conservation Districts. Proper site selection and well-developed engineering plans were recognized as essential to meeting the objective of wildlife habitat improvement. However, it was also recognized that once the impoundment is constructed and flooded, the major tool for subsequent management was manipulation of water levels.

After the New York State program had been in effect for 4 years, the need was recognized to evaluate the effectiveness of the impoundments and to further refine management techniques. The first of a series of studies designed to do this attempted to describe vegetation changes associated with manipulating water levels in impoundments (Brumstad and Hewitt 1952). Benson and Foley (1956) then evaluated waterfowl use of small impoundments in New York State. They observed that impoundments tended to lose their attractiveness to waterfowl and became less productive after 3 years.

The next study reported from New York State involved soil and water chemistry associated with impoundments (Cook and Powers 1958). The results of that study indicated that reduced productivity of impoundments may be related to accumulations of iron and manganese in the soil. Periodic drainage was advocated to aerate organic bottom soils, thereby reducing iron and manganese concentrations. However, yearly drawdowns are not recommended because excessive nutrient removal will result. The impoundments studied maintained productivity for at least 2 years after drawdown. Another point made was that the drawdowns--especially fall drawdowns--should be maintained through at least one growing season.

A concurrent study in New York State investigated succession of aquatic plants in impoundments (Dane 1959). The results indicated that depth of water level during the growing season was the single most important factor affecting the establishment of plant species. Woody cover continued to survive in impounded areas of shallow water (12-18 inches) that experienced a drawdown in summer.

Emerson (1961a, 1961b, 1962) studied vascular plants on the more than 1,000 impoundments constructed in New York up to 1960 and experimented with artificial establishment of food and cover plants. Although wild rice (*Zizania aquatica*) showed the greatest promise for propagation, the artificial establishment of wetland plants should only be considered after careful evaluation. All conditions must be suitable for the establishment of the plant before planting is started.

Other reports during the late 1950's and early 1960's suggested building impoundments in pairs with a biannual drawdown schedule (Uhler 1956), encouraged developing small impoundments near large water areas to improve hunting and harvest, and recommended obtaining easements or long-term leases for impoundment sites rather than outright purchase (MacNamara

1957). The importance of nongame species in wetlands and the aesthetic values of waterfowl were also beginning to receive recognition (Griffith 1957).

Three of the most significant studies concerning the use of drawdowns in the management of wetland habitats also took place during this period. Harris and Marshall (1963) initiated an intensive study on the effects of water level manipulation on marsh vegetation in northern Minnesota after noting the response of vegetation to drawdowns associated with dike repairs. After studying drawdowns and subsequent reflooding ranging from 1 to 5 years in length, they recommended an early or late summer drawdown lasting 1 year every 5 or 6 years. However, they also stated, "unless present limited knowledge of the consequences of drawdown is enlarged, the technique should be used only for specific purposes with proper control and study."

Kadlec's (1960, 1962) study of the effects of drawdown at the Backus Lake Impoundment in Michigan is still the most comprehensive evaluation of the effects of a drawdown on an impoundment. He concluded that drawdown first " . . produces a temporary abundance of food in the form of seeds of wetland plants; " second, " . . provides suitable conditions for the establishment of emergent cover; " and third, " . . may result in soil improvement and in improved aquatic plant food production upon reflooding." Although he felt that drawdown is a natural and effective method of maintaining the productivity of a waterfowl marsh, he also cautioned that drawdowns should be used only on an individual impoundment basis and that the technique is not a panacea for all marsh management problems.

Bednarik (1963a, 1963b) described the effects of water level manipulation on waterfowl harvest and wetland vegetation on the Magee Marsh Wildlife Area in northern Ohio. Drawdowns were used to induce dense stands of waterfowl food-producing vegetation which subsequently attracted large numbers of waterfowl to the marsh. Flooding was also used to eradicate widespread encroachment of undesirable vegetation.

Other States also began reporting programs of successful waterfowl management through impoundment construction and management (Fuller 1964, Spencer 1963). The State of Maine evaluated their small impoundment construction program from 1958 through 1960 and found it to be a cost-effective means of producing waterfowl. During the 1970's, case history reports on the effect of water level manipulation on vegetation in impoundments (Beard 1973, Mathiak 1971) and waterfowl response to habitat changes continued to appear in the literature.

A series of studies conducted from the late 1950's through the 1970's on glacial marshes in Iowa clearly documented the importance of natural drawdowns in unmanaged marshes (Weller and Fredrickson 1974, Bishop *et al.* 1979). The results indicated that productivity of the entire avian community increased after drawdown and subsequent reflooding. The greatest number and species of birds were present when there was a well-dispersed 50:50 ratio of vegetation to open water. The best way to obtain this condition was to wait 5 to 7 years between complete drawdowns.

From this point on investigations related to impoundments made an effort to address specific ecological phenomena related to wetlands with regulated water levels. Whitman's (1976) study in New Brunswick identified soil, water, vegetation, and aquatic macroinvertebrates as factors that determine level of use of impoundments by waterfowl, and examined correlations between impoundment age and those factors. He also recommended drawdowns every 5 to 7 years to maintain productivity in the impoundment.

Lathwell *et al.* (1969, 1973). and Bouldin *et al.* (1973) made intensive studies on the growth and chemical composition of aquatic plants and the changes in water chemistry in man-made marshes in New York State. Harter (1966) reported on the effect of water levels on soil chemistry and vegetation on Magee Marsh in Ohio. Studies also recommended manipulation of water levels to make seeds and invertebrates located in the bottom soils of impoundments available to waterfowl during periods of high energy requirements, such as pre-egg laying and egg laying (Jemison and Chabreck 1962, Baldassarre 1980). Research also continued to refine the concept that the use of drawdowns in managed impoundments is the most economical and efficient method to maintain desired habitat (Kaminski and Prince 1981).

Impoundments became widely accepted for managing wetlands in the 1960's (Hamor *et al.* 1968). In an effort to expand multiple-use management, impoundment construction expanded on the Chippewa National Forest in 1966 to convert sedge meadows and shrub swamps into primary wetland habitat (Hawkins and Green 1966). To date, 49 impoundments have been constructed on the Forest; construction is planned on about 40 more (table 1) (unpublished information, USDA Chippewa National Forest). Increased waterfowl use of the Forest with managed wetlands has been documented (Mathisen 1970).

Although the importance of managed wetlands to non-game wildlife species and aesthetics were alluded to in the past, production of ducks continued to be the prime objective of wetland management. This began to change in the 1970's and 1980's as other values

Table 1.--*Impoundments constructed for wildlife management on the Chippewa National Forest, north-central Minnesota*

Impoundment name	Area	Date of construction	Cost of construction
	Acres		*Dollars*
Day Creek Lake[1]	85	1956	--
Burns Lake[1]	9	1963	3,000
Seelye Point[1]	15	1964	500
Two Mile Lake	30	1964	5,000
Westbanks I	19	1964	1,000
Sucker Bay	41	1967	6,800
E. Pike Bay[1]	12	1968	1,000
Ball Club	78	1968	6,000
Highway 6	14	1968	7,560
N. Twin Lake[1]	5	1969	500
Loon Lake	119	1969	9,800
Wabana Lake[1]	10	1969	14,000
Welch Lake	33	1970	13,533
Cuba	34	1970	12,700
Grass Lake	70	1970	6,753
Highland Creek	47	1970	7,923
Amik Lake[1]	108	1970	8,240
Bear Brook	58	1970	14,043
Spur Lake	185	1970	18,800
Bag Lake	37	1970	12,061
Multiple use area	149	1971	6,500
Brush Lake	27	1971	13,024
Birch Lake	20	1971	6,782
East Lake	15	1971	5,176
LaCroix I	26	1971	7,240
Ketchum	51	1972	7,469
Pine Tree	113	1973	11,765
Beaver Lodge	77	1973	10,000
Crooked Lake	48	1973	6,000
Fletcher Creek	231	1973	10,000
Hanson Lake	95	1973	13,000
Cub	18	1975	4,000
Six Mile Brook	106	1975	20,000
Snake Brook	44	1975	10,000
LaCroix II	49	1975	8,500
Upper Third River	31	1976	10,000
Ojibway[1]	5	1976	4,000
Egg Lake	49	1976	21,000
Westbanks II	26	1976	8,500
Woodtick	103	1976	36,500
Holland Lake	164	1977	27,000
Jingo Lake	25	1978	20,500
Eel Lake	57	1979	20,000
Experimental Forest	74	1979	22,000
Little Wolf	60	1979	25,500
Sugar Lake	182	1981	27,000

[1]Northern pike spawning area.

gained more attention (Reimold *et al.* 1980). Nonconsumptive use of rails and shore birds has increased (Odum 1977, Ruckel and Sadler 1977) and specific recommendations are now being made to manage impoundments for the benefit of waterfowl other than ducks (Rundle and Fredrickson 1981).

The value of managing wetlands through impoundment techniques was recognized by wildlife managers early in the development of the profession. Management techniques were developed and refined and several studies were initiated over the last 40 years to examine in depth, the ecological relationships of impoundments (table 2). However, effective and economical impoundment management practices are still not known with a great degree of certainty (Lathwell *et al.* 1969). Most of the practices, schedules, and regimes presently in use are based on experience rather than sound scientific principles. The comprehensive, management-based impoundment studies completed to date have indicated that specific, regional, or local investigations are needed to develop management recommendations that will be locally effective (Knighton 1982).

LITERATURE CITED

Baldassaree, G. A. Residual seeds as potential spring waterfowl foods in small, man-made impoundments. The Prairie Nat. 12(1): 1-8; 1980.

Beard, T. D. Overwinter drawdown impact on the aquatic vegetation in Murphy Flowage, Wisconsin.Tech. Bull. 61; Madison, WI: Wisconsin Department of Natural Resources; 1973. 14 p.

Bednarik, K. E. Marsh management techniques, 1960. Ohio Department of Natural Resources, Game Research in Ohio. 1: 132-144; 1963a.

Bednarik, K. E. Water manipulations and waterfowl harvests of the Magee Marsh. Ohio Department of Natural Resources, Game Research in Ohio. 2: 145-158; 1963b.

Bellrose, F. C., Jr.; Brown, L. G. The effect of fluctuating water levels on the muskrat population of the Illinois River Valley. J. Wildl. Manage. 5(2): 206-212; 1941.

Bellrose, F. C. Jr.; Low, J. B. The influence of flood and low water levels on the survival of muskrats. J. Mammal. 24: 173-188; 1943.

Benson, D.; Foley, D. Waterfowl use of small, man-made wildlife marshes in New York State. New York Fish and Game J. 36(2): 217-224; 1956.

Bishop, R. A.; Andrews, R. D.; Bridges, R. J. Marsh management and its relationship to vegetation, waterfowl and muskrats. Proc. Iowa Acad. Sci. 82(2): 50-56; 1979.

Bouldin, D. R.; Lathwell, D. J.; Goyette, E. A.; Lauer, D. A. Changes in water chemistry in marshes over a 12-year period following establishment. New York Fish and Game J. 20(2): 129-146; 1973.

Bourn, W. S.; Cottam, C. The effect of lowering water levels on marsh wildlife. Trans. North Am. Wildl. Conf. 4: 343-350; 1939.

Bradley, B. O.; Cook, A. H. Small marsh development in New York. Trans. North Am. Wildl. Conf. 16: 251-264; 1951.

Brumstad, H. W.; Hewitt, O. H. Early investigations on artificial marsh development in New York. Trans. North Am. Wildl. Conf. 17: 259-268; 1952.

Carney, D. F.; Chabeck, R. H. Spring drawdown as a waterfowl management practice in a floating fresh marsh. Proc. Ann. conf. Southeastern Assoc. Fish Wildl. Agencies 31: 266-271; 1977.

Cartwright, B. W. Muskrats, duck production and marsh management. Trans. North Am. Wildl. Conf. 11: 454-457; 1946.

Cook, A. H.; Powers, C. F. Early biochemical changes in the soils and waters of artificially created marshes in New York. New York Fish and Game J. 5(1): 9-65; 1958.

Cox, W. T. Marsh firebreaks . . . a boon to wildlife. Am. For. 45(3): 109-111, 137; 1939.

Dachnowski-Stokes, A. P. Improvement of unproductive and abandoned peatland for wildlife and related uses. Ecology 20(2): 187-197; 1939.

Dane, W. W. Succession of aquatic plants in small artificial marshes in New York State. New York Game and Fish J. 6(1): 57-76; 1959.

Emerson, F. B., Jr. Experimental establishment of food and cover plants in marshes created for wildlife in New York State. New York Fish and Game J. 8(2): 130-144; 1961a.

Emerson, F. B., Jr. Some aspects of the ecology and management of wildlife marshes in New York State. New York State P-R Proj. W-88-R-5, Final Rep., 1961b; 115 p.

Emerson, F. B., Jr. The vascular plants of some marshes created for wildlife in southcentral New York. New York Fish and Game J. 9(1): 37-43; 1962.

Errington, P. L. Environmental control for increasing muskrat production. Trans. North Am. Wildl. Conf. 13: 596-606; 1948.

Fuller, R. W. Ecological response to impoundment of water. Vermont P-R Proj. W-33-R-1, 1964; 8 p.

Griffith, R. Improving waterfowl habitat. Trans. North Am. Wildl. Conf. 13: 609-618; 1948.

Griffith, R. E. Management of waterfowl habitat on the National Wildlife Refuges. Trans. North Am. Wildl. Conf. 22: 215-220; 1957.

Hamor, W. H.; Uhlig, H. G.; Compton, L. V. Ponds and marshes for wild ducks on farms and ranches in the

Table 2.--*Summary of selected impoundment studies conducted in North America*

Source	Wetland description	Drawdown schedule	Objective	Results
Dane 1959	Wildlife ponds, New York	Natural drawdown	Evaluate succession after reflooding	Some emergent food plants established; submergent food plants increased but declined substantially in 5 years; submergents limited by water transparency; emergents limited to 60 cm of water.
Kadlec 1962	Backus Lake impoundments, Michigan	Spring-summer drawdown, fall refill	Evaluate succession after reflooding	Increase in plant nutrients; invertebrate populations reduced; plant species composition not notably affected; most emergent species increased; food production during drawdown was
Bednarik 1963a	Magee Marsh impoundment, Ohio	Spring-summer drawdown, fall refill	Encourage waterfowl food plants	Good production of food plants for 4 years
Harris and Marshall 1963	Impoundments, Agassiz National Refuge, Minnesota	1 to 5 years continuous drawdown	Evaluate succession during drawdown and after reflooding	Emergents invaded wetter soils after drawdown but decreased quickly with reflooding; dense willow established on drier sites in 5 years.
Beard 1973	Impoundment, Murphy Flowage, Wisconsin	October to April	Reduce submergent and floating-leaf vegetation	Drastic reduction in submergents and floating-leaf vegetation.
Weller and Fredrickson 1974	Impoundment, glacial marsh, Iowa	Two summers, one winter	Encourage emergents	Emergents increased during drawdown, then decreased. Pre-drawdown densities in 6 years. Submergents increased after reflooding (2-3 years) then decreased.
Whitman 1976	Impoundments, New Brunswick	New, no drawdown	Study factors associated with aging impoundments	Terrestrial vegetation replaced in one year by sedge and cattail; progression towards rooted aquatics low in food value occurred; submerged and floating-leaf vegetation established, but declined as impoundments aged.
Carney and Chabeck 1977	Impoundment, Louisiana	May through August	Encourage waterfowl food plants	Waterfowl food plants were successfully established.
Klopatek and Stearns' 1978	Impoundment, Theresa Marsh, Wisconsin	Spring to fall	Carp control, determine pre- and post-primary productivity.	Variety of mud flat species established during drawdown; emergents dominated first year after refill.

Northern Plains. USDA Farmers Bull. 2234: 16 p. 1968.
Harris, S. W.; Marshall, W. H. Ecology of water-level manipulations on a northern marsh. Ecology 44(2): 331-343; 1963.
Harter, R. D. The effect of water levels on soil chemistry and plant growth of the Magee Marsh Wildlife Area. Ohio Game Monogr. 2: 36 p. 1966.
Hartman, G. F. Management of central Wisconsin flowages. Wisconsin Conserv. Bull. 14(4): 19-22; 1949.
Hawkins, A. S.; Green, W. E. Waterfowl management opportunities in forested areas of the Lake States. Seattle, WA: Proc. Soc. Am. For.: 54-58; 1966.
Hewitt, O. H. Management of an artificial marsh in Southern Ontario for ducks and muskrats. Trans. North Am. Wildl. Conf. 7: 177-283; 1942.
Jemison, E. S.; Chabreck, R. H. The availability of waterfowl foods in coastal marsh impoundments in Louisiana. Trans. North Am. Wildl. Conf. 27: 288-300; 1962.
Kadlec, J. A. The effect of a drawdown on the ecology of a waterfowl impoundment. Game Div. Rep. 2276. Lansing, MI: Michigan Department of Conservation; 1960. 181 p.
Kadlec, J. A. Effects of a drawdown on a waterfowl impoundment. Ecology 43(2): 267-281; 1962.
Kaminski, R. R.; Prince, H. H. Dabbling duck and equatic macroinvertebrate responses to manipulated wetland habitat. J. Wildl. Manage. 45(1): 1-15; 1981.
Klopatek, J. M.; Stearns, F. W. Primary productivity of emergent macrophytes in a Wisconsin freshwater marsh ecosystem. Am. Midl. Nat. 100: 320-332; 1978.
Knighton, M. D. Vegetation dynamics in wildlife water-impoundments of north central Minnesota. St. Paul, MN: University of Minnesota; 1982. 182 p. Ph.D. thesis.
Lathwell, D. J.; Bouldin, D. R.; Goyette, E. A. Growth and chemical composition of aquatic plants in twenty artificial wildlife marshes. New York Fish and Game J. 20(2): 108-128; 1973.
Lathwell, D. J.; Mulligan, H. F.; Bouldin, D. R. Chemical properties, physical properties and plant growth in twenty artificial wildlife marshes. New York Fish and Game J. 16(2): 158-183; 1969.
Leopold, A. Game Management. New York: Charles Scribner's Sons; 1933. 481 p.
MacNamara, L. G. Marsh management in New Jersey. Proc. Northeastern Game Conf. 1948: 92-93; 1948.
MacNamara, L. G. Salt marsh development at Tuckahoe, New Jersey. Trans. North Am. Wildl. Conf. 14: 100-117; 1949.
MacNamara, L. G. Potentials of small waterfowl areas. Trans. North Am. Wildl. Conf. 22: 92-96; 1957.
Mathiak, H. A. Observations on changes in the status of cattails at Horicon Marsh, Wisconsin. Res. Rep. 66. Madison, WI: Wisconsin Department of Natural Resources; 1971. 15 p.
Mathisen, J. Some aspects of man-made impoundments on the Chippewa National Forest. Presented at seminar on Wildlife and Man-made Water areas. Northern Prairie Wildlife Research Center, April 15-16; Jamestown, ND: 1970.
Mendall, H. L. Breeding ground improvements for waterfowl in Maine. Trans. North Am. Wildl. Conf. 14: 58-64; 1949.
Nelson, N. F. Marsh development and management on artificial impoundments in Utah. Proc. Ann. conf. Western Assoc. State Game and Fish Comm. 32: 207-209; 1953.
Odom, R. R. Sora (*Porzana carolina*). In: Sanderson, G. C., ed. Management of migratory shore and upland game birds in North America. Int. Assoc. Fish and Wildl. Agencies; Washington, DC; 1977: 57-65.
Page, J. C.; Locke, S. B.; McCrory, S. H.; Grebe, G. W. What is or should be the status of wildlife as a factor in drainage and reclamation planning. Trans. North Am. Wildl. Conf. 3: 109-125; 1938.
Penfound, W. T. Vegetation of Lake Chicot, Louisiana in relation to wildlife resources. La. Acad. Sci. 12: 47-56; 1949.
Penfound, W. T.; Schneidau, J. D. The relation of land reclamation to aquatic wildlife resources in southeastern Louisiana. Trans. North Am. Wildl. Conf. 10: 308-318; 1945.
Pirnie, M. D. Muskrats in the duck marsh. Trans. North Am. Wildl. Conf. 6: 308-313; 1941.
Reimold, R. J.; Hardisky, M. A.; Phillips, J. H. Wetland values - a non-consumptive perspective. J. Environ. Manage. 11: 77-85; 1980.
Ruckel, J. M.; Sadler, K. C. The resources and their values: distribution and abundance. In: Sanderson, G. C., ed. Management of migratory shore and upland game birds in North America. Int. Assoc. Fish and Wildl. Agencies, Washington, DC; 1977: 323-327.
Rundle, W. D.; Fredrickson, L. H. Managing seasonally flooded impoundments for migrant rails and shorebirds. Wildl. Soc. Bull. 9(2): 80-87; 1981.
Speake, E. W. Waterfowl use of creeks, beaver swamps, and small impoundments in Lee County, Alabama. Proc. Ann. Conf. Southeastern Assoc. Game and Fish Comm. 9: 178-185; 1955.
Spencer, H. E. Jr. Man-made marshes for Maine waterfowl. Maine Game Div. Bull. 9: 79 p. 1963.
Truax, W. C.; Gunther, L. F. The effectiveness of game management techniques employed on Horicon

Marsh. Trans. North Am. Wildl. Conf. 16: 326-330; 1951.

Uhler, F. M. Control of undesirable plants in waterfowl habitats. Trans. North Am. Wildl. Conf. 9: 295-303; 1944.

Uhler, F. M. New habitats for waterfowl. Trans. North Am. Wildl. Conf. 21: 453-469; 1956.

Weller, M. W.; Fredrickson, L. H. Avian ecology of a managed glacial marsh. The Living Bird 12: 269-291; 1974.

Weller, M. W.; Spatcher, G. E. Role of habitat in the distribution and abundance of marsh birds. Spec. Rep. 43. Ames, IA: Iowa Agriculture and Home Economics Experiment Station; 1965. 31 p.

Whitman, W. R. Impoundments for waterfowl. Occas. Pap. 221. Environment Canada, Ottawa, Ontario: Canadian Wildlife Service; 1976. 21 p.

Wilde, S. A.; Youngberg, C. T.; Hovind, J. H. Changes in composition of groundwater, soil fertility, and forest growth produced by the construction and removal of beaver dams. J. Wildl. Manage. 14(2): 123-128; 1950.

Yeager, L. E.; Anderson, H. G. Some effects of flooding and waterfowl concentration on mammals of a refuge area in Central Illinois. Am. Midl. Nat. 31: 159-178; 1944.

Zimmerman, F. R. Water levels in relation to furbearers and waterfowl in central Wisconsin. Wisc. Conserv. Bull. 8(1): 23-26; 1943.

WILDLIFE IMPOUNDMENTS IN THE NORTH CENTRAL STATES: WHY DO WE NEED THEM?

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In the north central United States with countless lakes and abundant wetlands, why provide more surface water through construction of impoundments?

This valid and logical question, asked countless times, deserves a valid and logical answer. I will explore the answer by answering four related questions:

1. What is the reason for constructing them?
2. Do impoundments really improve wetland habitat for wildlife.
3. Is there a shortage of natural aquatic communities functioning in a manner similar to impoundments?
4. Can we measure the cost-effectiveness of water impoundments?

I will formulate the discussion using data and experience gathered over 20 years on the Chippewa national Forest in north central Minnesota, and will assume that generally the results apply throughout the forested area of the Lake States. Other speakers will supplement my somewhat generalized discussion with more specific data.

IMPOUNDMENT OBJECTIVES-- WHY DO WE BUILD THEM?

The objectives of altering wetland habitat with low-head dams have gone through an evolutionary process. Objectives today are more complex than those of 20 years ago. Clearly, increasing waterfowl production and duck hunting opportunities was the primary objective during the early years. Drainage of prairie wetlands was destroying significant acreages of waterfowl production habitat. It was reasoned that some of this loss could be mitigated by improving the more secure wetlands in forested areas where there was also a substantial amount of public land (Hawkins and Green 1966). This continues to be a valid objective for creating impoundments, especially where agency missions and funding sources respond to the consumptive uses of hunting and trapping.

During the seventies when the term "nongame" wildlife was spawned, managers were seriously considering the effects of habitat manipulation on the nonconsumptive aspects of wildlife. Words such as "diversity," "communities," "species richness," and "holistic" appeared in the vocabularies of wildlife managers. The waterfowl production and harvest objective of wetland improvement, though still an important part of the whole, was considered within a broader context of community relationships among all vertebrates.

Special-status species, other than game and fur, were being recognized; these included "threatened" and "endangered," "sensitive" and "management indicator" species.

In the National Forest System, diversity itself is a wildlife management objective, mandated by the National Forest Management Act (Siderits and Radtke 1977). The purpose of the diversity objective is to achieve stability in the ecological sense, and to provide both game and nongame recreational opportunities. The simplest measure of diversity is the number of species, termed species richness (MacArthur 1965). I will use this term throughout the paper.

The objectives for creating wildlife impoundments, therefore, are: (1) enhancement of diversity, encompassing the entire range of species; and (2) improvement of habitat for selected groups of species having a special status.

PERFORMANCE--DO IMPOUNDMENTS IMPROVE UPON NATURAL WETLANDS?

Having defined in a general sense what managers are trying to accomplish with an impoundment, I can now compare natural aquatic communities to the habitat produced by low-head dams in terms of their ability to reach objectives.

All Wetlands Are Not Equal

Each wetland community has a unique assemblage of vertebrate fauna. Some are more diverse than others; some are more important for game and fur species. Some are used primarily for feeding, while others are more important as breeding habitats. Some are relatively more important to birds; others are more important to mammals or reptiles and amphibians. The next step is to sort all of this out.

Wildlife Habitat Association Data Base

A database assembled for the Chippewa National Forest provides a systematic way to predict the effects of habitat alteration on all vertebrates, excluding fish (Mathisen 1980). It also facilitates the ranking and assessment of habitat types (called communities) in terms of species richness and other parameters.

The database consists of nine interrelated elements that correlate 310 vertebrate species with habitat, season of use and status. Twenty-four communities, described by Niemi and Pfanmuller (1979), were modified to accommodate the vertebrates on the Chippewa. They reflect a combination of vegetation, successional stage, and structure. Eight of these are aquatic communities.

Each species was categorized by the communities utilized for feeding and/or breeding. Because most species are oriented to more than one community, an attempt was made to assign one of these communities as particularly important. This was termed the "critical community" for a species. It was impossible to assign a critical community to the more ubiquitous species.

Eight categories were used to relate special habitat requirements to each species, (man-made structures, edge, decaying log, snags, riparian areas, mast and banks or bare ground). Each species was also categorized for season of use (migration, summer, winter, permanent resident) and status (threatened, endangered, sensitive, game/fur, indicator). The data were entered on an IBM OS/6 Word Processor for storage and manipulation, and to facilitate updating.

Species Associated With Aquatic communities

The eight aquatic communities will be the framework for assessing performance and predicting the effects of altering wetlands by impoundment. Communities described below are given a descriptive name, and the appropriate classification according to the National Wetland Inventory System (Cowardin *et al.* 1979), is shown parenthetically.

Lake (Lacustrine/Limnetic Permanently Flooded)--This habitat is the open water of lakes at least 10 acres in size. Included are unvegetated beaches and mud flats, but no areas of emergent vegetation.

Woodland Pond (Palustrine/Aquatic Bed/Permanently Flooded)--This community is similar to a lake, except it is less than 10 acres in size and maximum depth is less than 6 feet.

Streams and Rivers (Riverine/Lower Perennial)--This community consists of open, moving water. It does not include associated areas of emergent vegetation.

Emergent Nonpersistent (Palustrine/Emergent/Nonpersistent/Intermittently Exposed or Lacustrine/Littoral/Emergent/Nonpersistent)--This community is a wetland or the littoral zone of a lake with emerging vegetation that does not persist due to die-back or ice action (e.g., wild rice, bulrush). If associated with a river or stream, it is in the Riverine System.

Emergent Persistent (Palustrine/Emergent/Persistent/Seasonally Flooded or Semipermanently Flooded)--This has emergent vegetation that persists through the winter (e.g., cattails, reed). There is no Emergent Persistent community associated with lakes and rivers in the NWI System.

Sedge Meadow (Palustrine/Emergent/Persistent/Saturated or Seasonally Flooded)--A type of Emergent Persistent Community, this was listed separate because of its importance on the Chippewa National Forest. It is a densely vegetated wetland of sedges, grasses and annuals; sometimes a floating mat.

Shrub Swamp (Palustrine/Scrub-Shrub/Broad-leaved Deciduous)--This wetland is dominated by woody vegetation, usually alder and/or willow. Trees are absent.

Open Heath Bog (Palustrine/Scrub-Shrub/Broad-leaved Evergreen/Saturated)--This wetland is characterized by a bed of sphagnum moss (often a floating mat) with leatherleaf, Labrador tea and other heaths dominating. There are very few trees (if present they are stunted) or broad-leaved shrubs.

Table 1 shows the number of species occurring on the Chippewa National Forest associated with these eight communities for feeding and/or breeding. Table 2 shows the number of special status species having an orientation to these communities. From these data, we can conclude that:

1. The shrub swamp community provides suitable

Table 1.--*Number of species that feed and/or breed in eight aquatic communities, Chippewa National Forest*

Community	Feeding	Breeding	Both	Total
Shrub swamp	49	2	42	93
Lake	66	-	5	71
Sedge meadow	40	4	23	67
Emergent persistent	35	4	25	64
Emergent nonpersistent	42	5	14	61
Pond	49	4	6	59
Heath bog	32	2	24	58
Stream and river	50	2	5	57

habitat for the most species, especially for breeding purposes.

2. While the open water of lakes ranks second in species richness, the use is almost entirely for feeding.
3. The heath bog and stream have the lowest level of species richness among the 8 communities.
4. Special-status species, as a group, are highly oriented to the emergent persistent and emergent nonpersistent communities. These are largely game/fur species.
5. Sensitive species are particularly associated with the heath bog, sedge meadow, and open water of lakes and ponds.

Organized information on the relative importance of aquatic communities to vertebrates is provided by the database and can now be used to assess the effects of altering these communities and to address the question: Does an impoundment provide suitable habitat for more species than does its natural predecessor?

Table 2.--*Number of special status species with an orientation to eight aquatic communities, Chippewa National Forest*

Community	Game/ fur	Thrt/ endg	Sensi- tive	Total
Emergent nonpersistent	27	-	3	30
Emergent persistent	26	1	3	30
Lake	18	2	6	26
Sedge meadow	18	1	6	25
Shrub swamp	19	2	1	22
Pond	15	-	6	21
Stream and river	15	2	4	21
Heath bog	7	1	7	15

Effects of Altering Aquatic Communities With Low-Head Dams

Building a wildlife impoundment usually results in the conversion of one community to a combination of other, presumably more valuable communities. The database can be used to assess these effects in terms of impoundment objectives.

Impoundment sites are generally selected to convert relatively monotypic wetlands, usually sedge meadows, shrub swamps, and occasionally lowland deciduous forests to complexes consisting of ponds, emergent persistent, emergent nonpersistent, and shrub swamp communities. Numerous combinations of amount and varieties of communities are possible within an impoundment. Biologists have always maintained that the more the variety and complexity, the greater will be productivity and species richness--but, how much greater is it? I can deal with the question by using the database to assess four typical conversions.

Case 1.--*Sedge meadow converted to an impoundment consisting of pond, emergent persistent, and emergent nonpersistent communities.*

Table 3 displays existing habitat suitability by class of vertebrate and type of use for the sedge meadow before flooding, and for the impoundment after flooding. Table 4 shows the effects of this conversion on special status species. From these the following conclusions can be reached:

1. Potential species richness is increased by 25 species, or 3 percent.
2. Habitat suitability for birds is particularly enhanced in the impoundment, increasing by 19 species, or 42 percent.
3. Habitat suitability for mammals remains about the same, although fewer breed in the impoundment.

Table 3.--*The effect of converting a sedge meadow to a comlex of pond, emergent nonpersistent and emergent persistent on species richness*

(In number of species)

	Before				After			
	Feeds	Breeds	Both	Total	Feeds	Breeds	Both	Total
Birds	27	3	15	45	48	-	16	64
Mammals	6	1	8	15	11	-	3	14
Herps	7	-	-	7	3	5	6	14
Total	40	4	23	67	62	5	25	92

Table 4.--*The effect of converting sedge meadow to a complex of pond, emergent nonpersistent, and emergent persistent on special-status species*

(In number of species)

	Before				After			
	Game /fur	Sens.	T/E	Total	Game /fur	Sens.	T/E	Total
Birds	12	4	-	16	23	5	1	29
Mammals	6	2	1	9	6	2	-	8
Herps	-	-	-	-	1	-	-	1
Total	18	6	1	25	30	7	1	38

4. Habitat suitability for reptiles and amphibians increases by 7, or 50 percent.
5. Habitat suitability for game/fur species increases by 66 percent, while the effect on other special-status species remains essentially unchanged.

Species composition within the impoundment will change considerably from that in the sedge meadow. Vertebrates using the sedge meadow as a critical habitat (such as marsh hawks, yellow rails and snowy owls) will be displaced. The new community complex will be suitable for a variety of waterfowl, gulls, loons, kingfishers, water shrews, and chorus frogs, to name a few.

Case 2.--*Shrub swamp converted to an impoundment consisting of pond, emergent persistent, and emergent nonpersistent communities.*

Flooding a shrub swamp often entails the choice of retaining a portion, usually on the periphery, in the original shrub swamp community in addition to open water and other aquatic communities. This case assumes the shrub swamp is eliminated; case 3 assumes that some shrub swamp is retained.

Table 5 compares species associations before and after flooding. Table 6 does the same for special-status

Table 5.--*The effect of converting a shrub swamp to a complex of pond, emergent nonpersistent and emergent persistent on species richness*

(In number of species)

	Before				After			
	Feeds	Breeds	Both	Total	Feeds	Breeds	Both	Total
Birds	34	2	26	62	48	-	16	64
Mammals	9	-	11	20	11	-	3	14
Herps	6	-	5	11	3	5	6	14
Total	49	2	42	93	62	5	25	92

Table 6.--*Effect of converting a shrub swamp to a complex of pond, emergent nonpersistent, and emergent persistent on special-status species*

(In number of species)

	Before				After			
	Game /fur	Sens.	T/E	Total	Game /fur	Sens.	T/E	Total
Birds	10	1	-	11	23	5	1	29
Mammals	9	1	1	11	6	2	-	8
Herps	-	-	-	0	1	-	-	1
Total	19	2	1	22	30	7	1	38

species. From these data we can conclude that:

1. Potential species richness remains about the same.
2. The habitat is suitable for fewer breeding species in the impoundment than in the original shrub swamp.
3. The impoundment produces a significant shift to game/fur species (58 percent increase), and is also more suitable for threatened, endangered, and sensitive species.

The mix of species is drastically different after flooding. Many species, especially birds associated with the shrub swamp, are displaced because of the transitional nature of this community. Species such as cuckoos, ruffed grouse, and various woodpeckers, warblers, and sparrows will be displaced. But many waterfowl, rails and shorebirds--absent in the original shrub swamp--will find the impoundment habitat suitable.

Case 3.--*Shrub swamp converted to an impoundment consisting of pond, emergent persistent, and emergent nonpersistent communities with some shrub swamp remaining.*

Tables 7 and 8 display the effects of an impoundment having the potential to retain a portion of the

Table 7.--*The effect of converting a shrub swamp to a complex of pond, emergent nonpersistent and emergent persistent and shrub swamp on species richness*

(In number of species)

	Before				After			
	Feeds	Breeds	Both	Total	Feeds	Breeds	Both	Total
Birds	34	2	26	62	69	-	42	111
Mammals	9	-	11	20	15	-	13	28
Herps	6	-	5	11	3	1	11	15
Total	49	2	42	93	87	1	66	154

Table 8.--*Effect of converting a shrub swamp to a complex of pond, emergent nonpersistent, and emergent persistent and shrub swamp on special-status species*

(In number of species)

	Before				After			
	Game /fur	Sens.	T/E	Total	Game /fur	Sens.	T/E	Total
Birds	10	1	-	11	27	5	1	33
Mammals	9	1	1	11	11	3	1	15
Herps	-	-	-	0	1	-	-	1
Total	19	2	1	22	39	8	2	49

area in the shrub swamp community, and if water level management strategy provides for its maintenance. We can conclude that:

1. Species richness increases from 93 to 154, or 66 percent.
2. The habitat is suitable for 50 percent more species of breeding birds.
3. The habitat is suitable for 95 percent more game/fur species, almost double that of the original community.
4. There are 67 percent more species accommodated than in an impoundment with no shrub swamp component.

Case 4.--*Lowland deciduous woodland converted to an impoundment consisting of pond emergent persistent and emergent nonpersistent communities.*

Although less common than other conversions, a wooded community is occasionally involved in an impoundment project. From tables 9 and 10 we can conclude that:

1. Species richness is increased by 33 percent, mostly for feeding purposes.

Table 9.--*The effect of converting a mature lowland deciduous community to a complex of pond, emergent nonpersistent and emergent persistent on species richness*

(In number of species)

	Before				After			
	Feeds	Breeds	Both	Total	Feeds	Breeds	Both	Total
Birds	6	5	29	40	48	-	16	64
Mammals	-	-	21	21	11	-	3	14
Herps	7	-	1	8	3	5	6	14
Total	13	5	51	69	62	5	25	92

Table 10.--*Effect of converting a mature lowland deciduous community to a complex of pond, emergent nonpersistent, and emergent persistent on special-status species*

(In number of species)

	Before				After			
	Game /fur	Sens.	T/E	Total	Game /fur	Sens.	T/E	Total
Birds	5	1	-	6	23	5	1	29
Mammals	6	2	1	9	6	2	-	8
Herps	-	-	-	0	1	-	-	1
Total	11	3	1	15	30	7	1	38

2. The habitat is suitable for more special-status species, especially game and fur species, increasing 153 percent in the impoundment.
3. The number of mammals that use the habitat for breeding is significantly reduced (from 21 to 3 species).

The changes in this case are the most dramatic in terms of species composition. A forested community supports very few wetland-oriented species and there is very little commonality among species in the deciduous woodland and the impoundment.

The Role of Lakes and Rivers

Lakes play an important role as wildlife habitat in the north central States. Our database shows 83 species with an orientation to lake and/or river habitat, primarily for feeding (table 1). Lakes are considered to be critical communities for 38 species. Among these are popular species such as common loons, bald eagles, and ospreys. Does the presence of lakes and rivers, therefore, preclude or diminish the need for constructing impoundments?

Just as all wetlands are not equal, neither are all lakes and rivers equal. Some are relatively monotonous open bodies of water with little emergent vegetation, while others have well-developed littoral zones of emergent nonpersistent communities. Lacustrine habitats do not have emergent persistent associations due to the effects of ice.

Table 11 shows the species relationships in a lake community with little or no littoral development, compared to one with a well-developed emergent nonpersistent community. Emergent vegetation provides suitable habitat for 36 additional species, mostly for breeding. A comparison of this community arrangement with a typical impoundment is shown in tables 12 and 13. Species richness and habitat suitability for

Table 11.--*Species associated with a lake community compared to a lake with an emergent nonpersistent component*

(In number of species)

	Lake only				Lake + emerg. nonpersistent			
	Feeds	Breeds	Both	Total	Feeds	Breeds	Both	Total
Birds	56	-	4	60	69	-	9	78
Mammals	8	-	-	8	11	-	3	14
Herps	2	-	1	3	3	5	7	15
Total	66	-	5	71	83	5	19	107

special-status species are very similar between the two, with the impoundment having a slight advantage for breeding. When the shrub swamp component is available in the impoundment, more species find it more suitable than the lake.

A factor to consider when comparing lakes to impoundments is scale. While there may be huge acreages of lake habitat, the portion used by most species is a narrow band of emergent vegetation interfaced with open water. Conversely, a typical impoundment or natural wetland complex is more efficiently utilized due to the interspersion and juxtaposition of its components.

Lakes and rivers are similar to impoundments in many respects, but notable differences make comparisons difficult. In any case they cannot be compared acre for acre.

The Riparian Effect

Of the 310 vertebrates occurring on the Chippewa National Forest, 115 or 37 percent are associated with riparian habitat. This important and productive zone

Table 12.--*Species richness in a lake with an emergent nonpersistent component compared to a typical impoundment (pond, emergent nonpersistent and emergent persistent)*

(In number of species)

	Lake + emerg. nonpersistent				Impoundment			
	Feeds	Breeds	Both	Total	Feeds	Breeds	Both	Total
Birds	69	-	9	78	48	-	16	64
Mammals	11	-	3	14	11	-	3	14
Herps	3	5	7	15	3	5	6	14
Total	83	5	19	107	62	5	25	92

Table 13.--*Special-status species associated with a lake with emergent nonpersistent component compared to a typical impoundment (pond, emergent nonpersistent and emergent persistent)*

(In number of species)

	Lake + Emerg. Nonpersistent				Impoundment			
	Game /fur	Sens.	T/E	Total	Game /fur	Sens.	T/E	Total
Birds	27	5	2	34	23	5	1	29
Mammals	6	2	-	8	6	2	-	8
Herps	1	-	-	1	1	-	-	1
Total	34	7	2	43	30	7	1	38

where water and upland come together is inherent in all communities with surface water (Thomas *el al.* 1979).

The effect on wildlife, therefore, of producing surface water in a wetland where none existed previously, includes riparian species that are not directly associated with aquatic habitats. The number of upland species affected at any given site depends on the type of upland community(ies) adjacent to the impoundment. The database indicates that 17 additional, upland vertebrates potentially benefit from the creation of riparian habitat (8 birds, 7 mammals, 2 reptiles). Among them are pileated woodpeckers, barred owls, flying squirrels, and garter snakes.

SUPPLY--IS THERE A SHORTAGE OF NATURAL AQUATIC COMMUNITIES?

The next step is to determine if enough wetland habitat similar to impoundments is available so that creating more may be precluded.

The existing wetland inventory on the Chippewa is based on Shaw and Fredine (1956) and is similar to the community classification in the database. Unfortunately, we have no reliable inventory data on emergent communities associated with lakes and rivers.

Table 14 shows the number of acres and the proportions of various communities based on our inventory of 1965. I have combined the shallow marsh and deep marsh types, considering that these are analogous to the emergent communities used in the database. These types are also similar to impoundment habitat.

"Impoundment-like" habitat, exclusive of lakes and rivers, accounts for approximately 7.5 percent of the

Table 14.--*Community composition, Chippewa National Forest*

Community type	Acres	Percent
	Number	
Lake (limnetic zone)	319,500	60.9
River and stream	2,876	0.5
Shrub swamp	86,116	16.5
Sedge meadow	59,458	11.4
Emergent[1]		
Wetland	13,067	2.5
Lake	28,400 (est.)	5.4
River	700 (est.)	0.2
Heath bog	11,609	2.2
Pond	2,217	0.4
Total	523,943	100.0

[1]Includes persistent and nonpersistent.

total wetland resource on the forest. Sedge meadows and shrub swamps, the communities most often targeted for conversion, account for 84.5 percent of the total wetland resource. Therefore, impoundment-like habitat is in relatively short supply and constructing impoundments to convert abundant sedge meadow and shrub swamp communities is justified in light of the performance of impoundments in meeting objectives.

Although there is no inventory of emergent communities associated with lakes and rivers, there are 347,888 acres of lake within the forest with 1,775 miles of shoreline, and about 600 miles of streams and rivers, totaling 3,576 acres.

If an estimated 20 percent of lake shoreline is vegetated with emergent communities (an educated guess) for an average distance of ⅛ mile from shore, an additional 28,400 acres of habitat similar to impoundments is provided. If 20 percent of the streams and rivers consists of emergent communities (a rough estimate, to be sure) another 700 acres of impoundment-like habitat is available. Even with these proportions, impoundment-like habitat is only 9.1 percent of the total aquatic resource, while the shrub swamp and sedge meadow total 27.9 percent.

ECONOMICS--CAN WE MEASURE COST-EFFECTIVENESS?

What about the appropriateness of constructing impoundments in terms of wildlife supply/demand, and the economics of cost-effectiveness?

In the past, we have attempted to measure these elusive factors, but studies lacked credibility and usually frustrated the biologists trying to apply economic theory that was barely understood.

I believe we are now on the threshold of better understanding. These economic measurements for impoundments are now available in draft form on the Chippewa National Forest. They will soon be published as part of the Forest Land Management Plan. The preliminary analysis, based on literature review and professional assumptions, indicate that demand for waterfowl, fur-bearers and nongame species will increase through 2030. The cost/benefit analysis, based on mandatory standards and methods, indicate a positive relationship for wildlife impoundment construction.

SUMMARY AND CONCLUSION

I have defined two broad objectives for creating impoundments, one dealing with diversity as an ecological concept, and the other relating to the welfare and production of particular groups of species, including game/fur, threatened/endangered and sensitive. By converting natural wetlands to impoundments, these objectives can be realized.

Species associated with eight aquatic communities were examined in terms of the two objectives. Then, results of converting some of these to impoundment complexes were examined. Converting monotypic wetlands to various combinations of aquatic communities by constructing low-head dams, produces variable effects on vertebrate species richness and species composition, depending on the communities involved. Animal diversity can be significantly increased, and the effect on game/fur and other special-status species is highly positive.

Lakes with well-developed littoral areas of emergent vegetation are similar to impoundment habitat in terms of species suitability, except in cases where the shrub swamp component is part of the impoundment complex. In this case, impoundment performance exceeds that of lake habitat.

Unlike natural wetlands and lakes, most impoundments have a capacity to sustain high-level productivity through water level manipulation to enhance characteristics such as shrub swamp borders and nutrient richness (Knighton 1982).

The wetland inventory of the Chippewa National Forest was examined to determine whether enough "impoundment-like" natural wetlands exist to preclude creating more with dams. Only 7.5 percent of the wetland resource on the forest is analogous to impoundment habitat in terms of vertebrate species suit-

ability; while 84.5 percent is comprised of the types most often targeted for conversion. Impoundments, therefore, serve to provide a more diverse community over the area, meeting the objectives of diversity and ensuring the habitat needs of special-status species are met.

Preliminary economic analyses indicate that the demand for waterfowl, fur-bearers, and nongame species will increase in the next half century. Economic measurements are not available in draft form for the Chippewa National Forest.

LITERATURE CITED

Cowardin, L. M.; Carter, V.; Golet, F. C.; LaRoe, E. T. Classification of wetlands and deepwater habitats of the United States. Washington, DC: U. S Department of Interior Fish and Wildlife Service; 1979. 103 p.

Hawkins, A. S.; Green, W. E. Waterfowl management opportunities in forested areas of the Lake States. Proc. Soc. of Am. Foresters, Seattle, WA: 1966: 54-58.

Knighton, M. D. Vegetation dynamics in wildlife water-impoundments of north central Minnesota. St. Paul: University of Minnesota; 1982. Ph.D. thesis.

Mathisen, J. E. Wildlife habitat associations, a data base. Cass Lake, MN: Chippewa National Forest; 1980.

Mac Arthur, R. H. Patterns of species diversity. Biol. Rev. 40: 510-533. 1965.

Niemi, G. J.; Pfanmuller, L. Avian communities: approaches to describing their habitat associations. In: Proceedings, Management of North Central and Northeast Forests for Nongame Birds; 1979: 154-177.

Shaw, S. P.; Fredine, C. G. Wetlands of the United States. Circular 39. Washington, DC: U. S. Fish & Wildlife Service; 1956. 67 p.

Siderits, K.; Radtke, R. Enhancing forest wildlife habitat through diversity. Trans. 42d North Am. Wild. & Nat. Res. Conf. 1977: 425-434.

Thomas, J. W.; Anderson, R. G.; Maser, C.; Bull, E. L. Wildlife habitats in managed forests in the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U. S. Department of Agriculture; 1979: 40-47.

SELECTION OF WATER IMPOUNDMENT SITES IN THE LAKE STATES

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Water can be impounded to provide habitat suitable for waterfowl, fur bearers, amphibians, reptiles, songbirds, and raptors. Selecting these sites requires considering several factors including: an inventory of wetlands, a topographic survey of potential sites to predict normal pool size and the final interspersion of water and vegetation, design criteria for low flows that are sufficient to maintain water levels throughout the summer, and design criteria for high flows which the dam must retain or pass. This chapter will focus on factors preceding dam design and list a number of considerations for prioritizing construction schedules.

WETLAND INVENTORIES

Throughout the forested, northern Lake States, water impoundment sites are mostly freshwater wetlands (specific conductance < 800 micromhos). These will have at least intermittent streams leaving them, occur at the beginning of perennial streams, or along the sides of a perennial stream. Impoundment proposals may be for a single site or for many sites derived from the evaluation of a wetland inventory.

Wetland inventories for any administrative unit are made to locate and classify areas according to management objectives. The objectives may include timber potential or stand establishment needs, drainage suitability, energy potential (on organic soils), and wildlife management potential aimed at fish, fur bearers, and waterfowl. Several wetland classification systems suitable for wildlife management potential include: Shaw and Fredine (1956) (Circular 39), Stewart and Kantrud (1971), Golet and Larson (1974), and Cowardin *et al.* (1979). The latter compares classification criteria among the four systems and is an excellent reference to consult first in planning an inventory. The few kinds of wetlands most important for impounding water for wildlife are listed in table 1 for two of the systems; many other classes are available for inventories with broader management objectives. The theory of inventorying wetlands will be discussed using the terminology of Circular 39.

Type 1 wetlands (seasonally flooded basins) are not included because they are difficult to inventory from a single set of aerial photos, particularly in forested areas (they are numerous in the Prairie Region, much less so in the Forested Region, but provide breeding pair habitat). Type 2 wetlands (sedge meadows) are of little importance to waterfowl because of little or no open water but may be used for nesting. Type 3 wetlands (shallow marshes) are extensively used by breeding pairs but frequently dry up before brood-rearing is completed. Type 4 wetlands (deep freshwater marshes) are the best breeding habitat and also serve as feeding places for migratory waterfowl. Type 5 wetlands (open water) are generally classified as lakes if their area exceeds 10 acres (4 ha). Emergent vegetation around the edge is used by broods. They do not require impounding unless adjacent wetlands can add substantial areas of interspersed water and vegetation by raising the lake level. Type 6 wetlands (shrub swamps) have low waterfowl use unless open water areas are well interspersed. Type 2, 3, and 6 wetlands can be converted into areas more suitable for waterfowl by impounding water and shifting their classification to type 4 (deep freshwater marshes).

Steps in the wetland inventory process follow.

1. Define the basic inventory unit.
   The basic inventory unit is broadly defined by administrative boundaries and should include outlines of other ownerships where potentially impounded wetlands may be precluded. Examples of a basic inventory unit include: a county, a ranger district, a refuge, etc. For large areas inventory units can be combined, such as combining ranger districts to cover an entire state or national forest, county, etc.
2. Obtain vertical aerial photos and USGS topographic maps that cover the entire inventory unit. Standard resource photography (9 × 9 inch in a variety of films) can be obtained at a scale of 1:24,000, which matches the USGS 7.5 minute series orthophoto map (topographic). However, ex-

Table 1.--*Most useful wetland classification units for areas suited to water-impoundments for wildlife (impounding types 2, 3, and 6 creates a type 4 wetland, most suitable for waterfowl production)*

Circular 39 type (Shaw and Fredine 1956)	Classification of wetlands and deepwater habitats (Cowardin 1979)		
	Classes	**Water Regimes**	**Water chemistry**
Type 2-Inland fresh meadows. Largely sedge meadows in the Lake States. They are without standing water during most of the growing season, but the soils are water logged within a few inches of the surface.	Emergent Wetland	Saturated	Fresh
Type 3-Inland shallow fresh marshes. In most years they retain water until mid-summer, but frequently dry up before brood-rearing is complete. Water is generally less than 6 inches (15 cm) deep.	Emergent wetland	Saturated	Fresh
Type 4-Inland deep fresh marshes. These are covered with water 6 to 36 inches (90 cm) or more during the growing season	Emergent wetland Aquatic	Permanently flooded Intermittently exposed Semipermanently flooded	Fresh
Type 6-Shrub swamps. These are usually waterlogged during the growing season and often covered with as much as 6 inches (15 cm) of water.	Scrub-shrub wetland	All nontidal regimes except Permanently floods	Fresh

isting photography at 1:15,840 can also be used. The minimum wetland acreage that can be mapped at these two scales is 6 acres (2.5 ha) and 2.5 acres (1 ha) respectively. For small units, small format (35 or 70 mm) aerial photography can substitute for or supplement the 9 × 9 standard (Meyer 1982).

3. Use the 9 × 9 photo with an acetate overlay to delineate and identify wetlands. You will be able to identify wetland type in most instances from the photo; use the orthophotomap for general location and drainage patterns.
4. To assist in dam siting, plan to make notations of both active and abandoned beaver dams, and primary wildrice producing areas that may help in prioritizing impoundment sites.
5. Arrange the air photos in either north-south or east-west flight strips. Start with the photo in the northeast corner of the basic inventory unit and work south to the southern border, then begin with the north photo of the next strip to the west and continue with this pattern until the next unit is completed.
6. Place an acetate overlay on each photo. Outline each wetland and indicate inflowing and exit streams with an arrow. Determine area with a dot grid. Label each wetland with three numbers (ex: 35-15-2). The first number is the individual wetland number starting with 1 and continuing throughout the entire inventory. The second number is area (acres or hectares). The third number is wetland type number (such as 2 for sedge meadow). If the type cannot be determined from the photo, underline the first two numbers to indicate that this wetland must be field-checked.
7. Outline other ownerships, mark beaver dams, note primary wild rice producing areas, outline lakes, and identify the overlay.
8. Identify the photo overlay by strip number and photo number in the strip in the upper right-hand corner. List township and range in the upper left corner of the overlay. Draw in and identify section corners. See figure 1 for an example overlay.
9. Record overlay information with the headings: wetland number, area, type, photo strip number, photo number, township, range, section, field checking needed, beaver dams, and comments on sites apparently suitable for impounding, including land acquisition needed, or cooperative ventures among land owners required.

The final product of a wetland inventory is a summary document for the basic inventory unit containing:

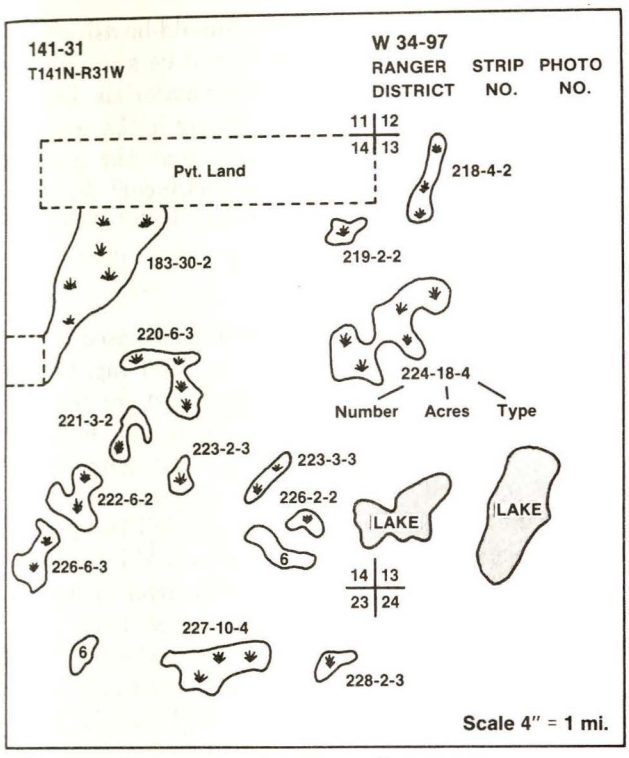

Figure 1.--*Sample Aerial Photo Overlay.*

1. Total number and areas of wetlands.
2. Relative abundance of wetland types.
3. Distribution of types by size classes.
4. Sites where there is impoundment potential.

BUILDING THE BEST POTENTIAL IMPOUNDMENT SITES FIRST

Shallow water impoundments are constructed to improve wetland habitat productivity. A host of things, (some of which will be explained in detail later) must be considered in choosing an area for dam construction. The following is a check list beginning with conditions that should rule out impoundment construction before detailed site work is done.

Do not construct an impoundment:

1. Where existing surface water has a specific conductance less than 25 micromhos, or where the watershed area to surface water area ratios are low (explained later).
2. That will destroy endangered plants.
3. On a stream designated as potable water or a trout stream by State agencies. Trout streams should not exceed 21° C (70° F) at summer maxima and should have gradients favored by viable brown trout populations. These gradients vary with stream width: 7-8 percent slope in streams up to 10 meters (30 feet) wide, 6-7 percent (10-23 meters wide), 5-6 percent (23-60 meters wide), 4.7-5 percent (60-90 meters wide), (Allen 1969). If both temperature and slope conditions exist the area should not be considered for impoundment. In very cold streams that do not exceed 10° C (50° F) impounding results in better fish growth (Waters 1977).
4. If a major spawning run is blocked.
5. If a significant amount of winter deer-yard cover is flooded.
6. If nearby lakes or roads will be flooded.

Give high priority to potential impoundment sites:

7. Where the development cost per acre is lowest. Limit flooded areas to 25 acres and more.
8. Where new road construction to the site is minimal.
9. Where existing roadways can be incorporated in the dam design.
10. Where narrow upland constrictions mean a shorter dam length.
11. Where new impoundments are within 1.6 kilometers (one mile) of other wetland types including lakes. This will encompass the minimum puddle duck home range for breeding pairs and broods.
12. Where land ownership is under one or two agencies or one individual.
13. Where islands and irregular shoreline exist.
14. Where 30 to 70 percent of the normal pool area will be less than 3 feet deep.
14. Where floating mats will not break loose and clog spillways.

EVALUATING A POTENTIAL IMPOUNDMENT SITE

The following evaluation steps were developed in north central Minnesota and tested for consistency of application by observations in forested areas of Wisconsin and Michigan. The area of application is defined in kind by Cowardin *et al.* (1979) as fresh water wetlands (< 800 micromhos) within the Palustrine and Riverine systems. They are defined in area by Bailey's (1976) Ecoregions encompassing the four sections of the Laurentian Mixed Forest within the warm continental division of the Humid Temperate domain. This includes the northeastern one-third of Minnesota, the northern half of Wisconsin, the northern two-thirds of Michigan, New York, Vermont, New Hampshire, Maine and adjacent areas of southern Canada exclusive of maritime zones. Some general principles will apply in other areas, but water quality guides need local derivation outside of these areas.

Topograhic Survey

A topographic survey at 1-foot contour intervals is required to calculate flood storage volume above a selected normal pool[1] elevation. (Note: consistently set the level rod in the bottom of a hollow to minimize elevation variation in hummock-hollow surfaces). In addition, a profile of acres flooded at various 1-foot depths can be used to calculate total normal pool area, area of open water, area of emergent vegetation, and the ratio of emergent vegetation to open water. A tabulation of this information will show where total impoundment area can be maximized while keeping the ratio of vegetation to water area at 30 to 50 percent. (See appendix A for details). These considerations must be made within the constraints of land ownership and other topographic controls. Having selected a normal pool elevation, there is still no guarantee that the impoundment site will hold water throughout the summer.

Avoiding an impoundment site that will not hold water or be of marginal use for waterfowl production requires the consideration or measurement of four additional things: area geology, watershed boundary, impoundment soils, and water supply. If three of them say "yes" (that is, construct the impoundment) and one says "no," a mistake in measurement or interpretation was probably made in at least one of the three positive areas. If all four things say "yes," then you can assume the site will have adequate water. These four areas of consideration follow; one leading into the next. If you get to the end and still affirm that the site will collect and hold water, proceed with designing a dam.

Geologic History

First, you should have a basic understanding of the glacial history of the administrative unit you are selecting sites from. This is available from soil surveys and texts or papers on pleistocene geology within your State. Become familiar with outwash plains, glacial lake beds, ground moraines, end moraines, and buried sand and gravel aquifers. This will give a general idea of the porosity of earth materials at the impoundment site and its surface and underground watersheds.

In the back of your mind, you should be asking the questions: How will water get to and be sustained at this potential site? Are there porous materials that act as a water conduit to the site? Where is the regional water table? Are there rock types that may yield a unique water quality (specific conductance)? Will bottom materials hold water or will they leak? Will fluctuations of 2 or 3 feet in the regional water table affect this site?

Obviously this area of consideration is based on experienced interpretation of a geologic setting. Get to know your pleistocene geology, and parts of the site evaluation puzzle will fit together with ease. Figure 2 depicts a typical geologic setting in north central Minnesota and the relation of several wetlands to the regional water table. Groundwater is high in specific conductance because of calcium dissolved from limestone fragments lying in a mixed horizon on top of deep bedrock. Specific conductance in wetlands indicates the size of surface drainage area or whether there is direct contact with the regional water table. With reference to specific conductance in the wetlands of figure 2, the 25 wetland has a small surface drainage basin, the 26-100 wetland has a large, surface water drainage basin, the 101-150 wetland has a mixture of surface and groundwater which may be dependent on the regional water table fluctuation, and the 151+ wetland has a strongly dominating groundwater flow.

Define the Watershed

Second, define the surface watershed from 7.5-minute series orthophoto maps (topographic). It is easy to make a mistake at this point. Do not use forest type maps, because the tendency in using type maps is to draw watershed boundaries around wetland types that are not in the immediate vicinity of the impoundment site. In the northern Lake States it is common for a portion of a watershed boundary to cut through a wetland. In other words, many peatlands straddle watershed boundaries. If you are in doubt, field check boundary wetlands for multiple drainage outlets and their direction of flow.

Once the boundary is delineated, determine watershed area by dot grid, planimeter, or paper cut-out weighing on an analytic balance. Record the area for later use.

Sample Impoundment Soils

Third, go to the impoundment site, select a spot near the stream channel, but above water, and auger to at least a depth of 5 feet. Record the depth, color and texture of horizons using gross "thumb and forefinger" estimates of texture. Also record the reaction of each

[1] *The "normal pool" is the area of water achieved by flooding to the top of the last stop log. It occurs at the design elevation for a stable water-level. Higher pools will occur during temporary flood storage and lower pools will occur during designed drawdowns or natural drawdown when evaporation exceeds water supply.*

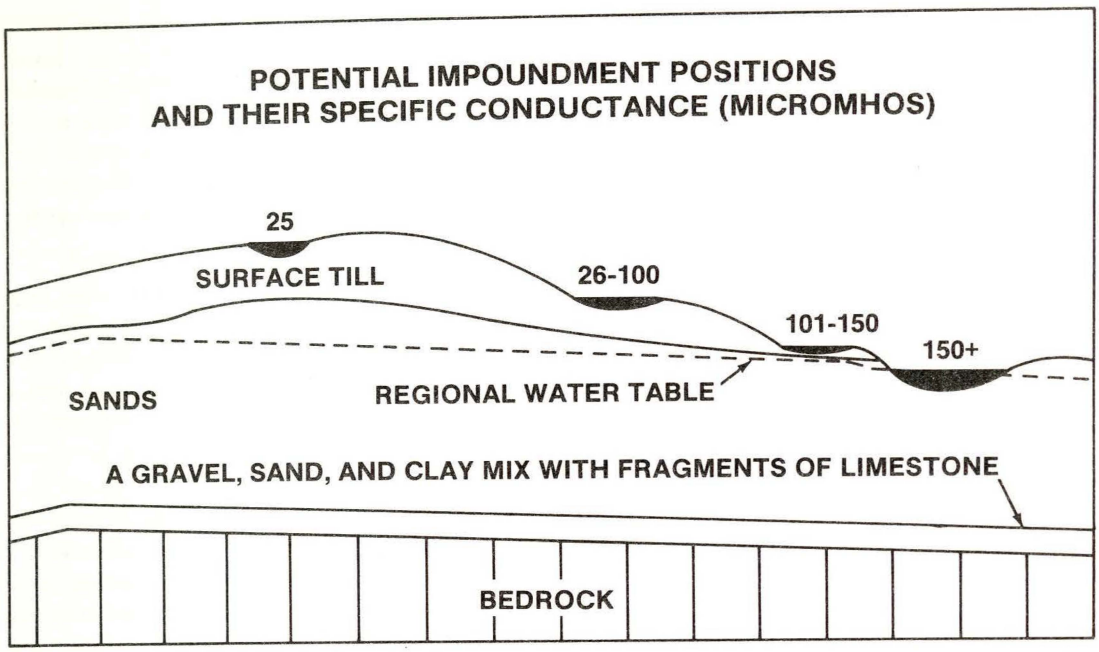

Figure 2.--*A typical geologic setting for wetlands in north central Minnesota. Water supply to wetlands can be increased if the wetland water table is the same as the regional water table.*

horizon to a 10 percent solution of HC1 as none, weak, moderate, or strong fizzing. Interpretation:

1. If organic horizons exceed 6 inches in depth and consist mostly of fibric materials (sample > ⅔ fibers), the organic mat will probably float after flooding.

a. This is based on the shallow rooting depth of wetland vegetation which is generally limited to 6 inches. Roots will extend into mineral soil through organic horizons less than six inches thick and serve to anchor the mat.

b. If thick fibric organic mats (0.5 to 3 feet) are found, you can predict where the mat will float by a survey of mat thickness. Productive impoundments can be made when mats float, but complete drawdown cycles will have little or no impact on mat vegetation in smaller impoundments (< 250 acres).

c. Maintenance surveys should pay particular attention to floating mats near the outlet. Large sections can break loose and clog emergency spillways and normal pool outlets.

d. Flooded peats (which are usually hemic or sapric in degree of decomposition and thus don't float) around the edges of large multi-purpose impoundments (1,000 acres plus in size) can be subject to severe erosion. The problem arises on areas receiving large spring runoff (> 1,000 cubic feet per second) if the impoundment is held at normal pool over winter. Then, if ice freezes deep enough to grab plant roots and the organic soil, spring flows will lift 6 inches or so of soil with the ice, pulverize it with wind-pushed ice, and flush it out in overflow. This annually deepens the shallow wildlife zone around an impoundment edge. In this situation erosion can be prevented by drawing water down during the winter. Begin drawdowns after 3 inches of ice have formed and drop the water-level to 2 to 3 feet. This provides for spring flood retention, but it also leaves a collapsed layer of 3 inches of ice on the top of the shallow areas with organic soil. These "mud flats" will melt out in the spring prior to the snowmelt peak flow. Starting drawdown with 3 inches of ice protects muskrat populations, otherwise drawdowns can start after the waterfowl season ends (Linde 1979).

2. Coarse sands to pebbles within the upper foot (may extend deeper).

a. Usually indicates a strong groundwater supply with a rapid delivery system (large pores) for spring snowmelt. At sites with a high risk dam, be certain that the watershed area is accurately defined so that emergency spillway design is adequate.

b. Water level control will be possible in most years. However, during very dry years the regional water table may drop below the bottom of the impoundment. Heavy rains and melt from deep snowpacks will be needed to bring the regional water table above the impoundment bottom. In other words, impoundments on deep sands have a very leaky bottom and water levels can be controlled only when the regional water table is higher than the dam bottom.

3. Horizons of *very fine* sand or silt or clay in the upper 5 feet.

a. Impoundments with these kinds of bottoms will hold water. If medium to fine sand horizons occur above the clay, silt, or very fine sand horizons, there is a good chance for a groundwater supply. If not, this does not rule out the possibility of a groundwater supply since it may discharge to the surface up-stream of the impoundment site in localized "artesian well" areas.

4. Strongly calcareous soils in the upper foot (reacts strongly to 10 percent HC1).

a. When calcareous soils occur within the upper foot it is necessary to rule out the use of specific conductance values in the water (described next) as an interpretation of groundwater supply. Assume that water supplies are of surface origin.

5. Strongly calcareous soils not present in the upper foot.

a. Use specific conductance of the water to interpret water supply characteristics and suitability of the site for impoundment.

Measure Specific Conductance of the Water

Fourth, measure specific conductance of the water during June, July, August, September, or October. Avoid snowmelt periods and sampling within 2 or 3 days of a large storm (over 1 inch). Adjust measurements (micromhos/cm) to 25° C by dialing the temperature correction knob to the ambient water temperature, or by adding 2 percent per degree for each degree centigrade below 25° C or subtracting 2 percent per degree for each degree centigrade above 25°. Interpretation:

1. Reading ≤ 25: Guaranteed to have only a surface water supply of limited amount. Waters this low in conductance have traveled only short distances and were able to dissolve only minor amounts of mineral salts. Do not build an impoundment. Open water covering the estimated normal pool area will exist only during the spring of the year.
2. Readings 26-100: Surface water collected from the surrounding watershed predominates. Water level control may be possible in average to wet years if watershed area to impoundment area (normal pool) ratios equal or exceed table values (see table 2 to calculate specific values, or locate the potential site in figure 3 for general values). Water levels will be controlled by climate in dry years or if area ratios are less than table values.
3. Readings 101-150: Increasing values in this range indicate that the amount of groundwater mixing with surface water is increasing, but the ground-

Table 2.--*Acres of watershed per acre of impoundment surface needed to ensure a dependable water supply in the northern Lake States*[1]

Annual streamflow (Inches)	Summer and fall streamflow	Inches of open water evaporation				
		24	26	28	30	32
	Inches	*Acre of Watershed/acre of impoundment water at normal pool*				
2	0.7	34	37	40	43	46
4	1.8	13	14	16	17	18
6	3.0	8	9	9	10	11
8	4.1	6	6	7	7	8
10	5.2	5	5	5	6	6
12	6.4	4	4	4	5	5
14	7.5	3	3	4	4	4
16	8.7	3	3	3	3	4

[1]Table derived from the equation

$$Y = \frac{\text{Inches of open water evaporation}}{-.46 + .57\ (\text{inches of annual streamflow})}$$

Y = Surface watershed acres needed per acre of normal pool

This equation is shown with inches of annual streamflow because annual values are easiest to obtain. The ratios in fact are based on summer and fall streamflow because this is the time when water supply must match open water evaporation. Spring streamflow (April and May) fills the impoundment and overflows. It doesn't help to maintain the water at normal pool during the summer when evaporation is high. The denominator is a regression of summer and fall streamflow against annual streamflow from a small surface water area over a range of annual precipitation.

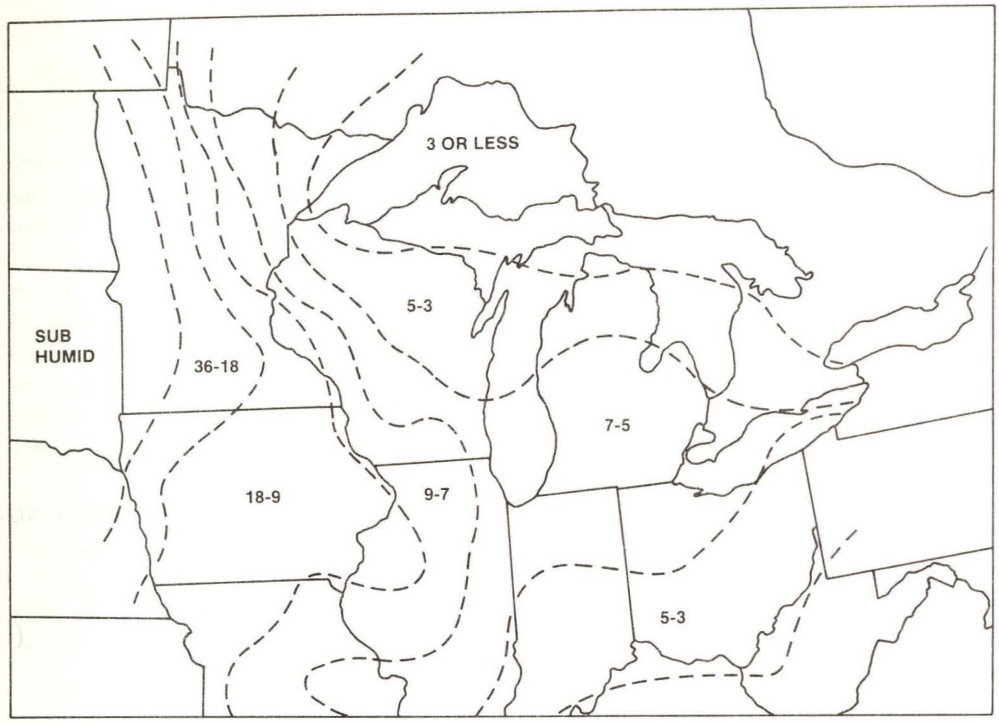

Figure 3.--*Zones of watershed-to-impoundment-area ratios sneeded to supply summer surface water runoff sufficient to maintain a normal pool water level.*

water does not dominate. Continue to rely on suitable watershed to impoundment area ratios.

4. Readings 151+: Groundwater dominates the supply to these impoundment sites. An adequate water supply is available during all but the most severe drought years. You can ignore area ratios. It may be that the surface watershed to impoundment area ratio is less than the table values; this means that the "ground-watershed" feeding the site is larger than the surface watershed.

If your knowledge in all four areas is compatible, then you're ready to consider dam construction and high-flow design criteria. If your knowledge is not compatible in all four areas, be suspect of your measurements and do them again.

LITERATURE CITED

Allen, K. Radway. Distinctive aspects of the ecology of stream fishes: a review, J. Fish. Res. Board of Canada 26(6): 1429-1438; 1969.

Bailey, Robert G. Description of the ecoregions of the United States. Ogden, UT: U.S. Department of Agriculture, Forest Service; 1976. 77 p.

Cowardin, Lewis M.; Carter, Virginia; Golet, Francis C.; LaRoe, Edward T. Classification of wetlands and deepwater habitats of the United States. FWS 10BS-79/31. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service, Office of Biological Services; 1979. 103 p.

Evans, Charles D.; Black, Kenneth E. Duck production studies on the prairie potholes of South Dakota. Special Scientific Report-Wildlife 32. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service, Office of River Basin Studies; 1956. 59 p.

Golet, Francis C.; Larson, Joseph S. Classification of freshwater wetlands in the glaciated northeast. Res. Publ. 116. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service; 1974. 56 p.

Linde, Arlyn F. The Winnebago pool: its water level management and the associated habitat problems. In: 3d annual meeting American Water Resources Association, Wisconsin Chapter. 1979. 13p.

Meyer, Merle P. Place of small-format aerial photography in resource surveys. J. For. 80: 15-17; 1982.

Shaw, Samuel P.; Fredine, C. Gordon. Wetlands of the United States their extent and their value to waterfowl and other wildlife. Circular 39. Washington, DC: U.S. Department of Interior, Fish and Wildlife Services; 1956. 67 p.

Stewart, Robert E.; Kantrud, Harold A. Classification of natural ponds and lakes in the glaciated prairie region. Res. Publ. 92. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife; 1971. 57 p.

Waters, Thomas F. The streams and rivers of Minnesota. Minneapolis, MN: University of Minnesota Press; 1977: 170-171.

APPENDIX A

OPTIMIZING IMPOUNDMENT AREA

A topographic survey at 1-foot intervals can be used to calculate flood storage volume. In addition to giving a profile of acres flooded at incresing 1-foot depths, it can be used to tabulate water area information. This can be used to maximize water impoundment area while keeping the ratio of vegetation to water area at 30 to 50 percent (or close) within engineering constraints.

There are three considerations for impoundment construction. They are:

1. Maximize the flooded area to reduce the per acre cost.
2. Make sure there is sufficient freeboard (distance from normal pool to top of the dam) to temporarily store flood waters while most of the water passes through the emergency spillway; and make sure that road beds, other outlets, and adjacent other-owner property are not flooded.
3. Keeping water and vegetation in a reasonable mix (interspersion).

Figure 4 shows how a 1-foot contour interval map of an impoundment site can be used to tabulate and display area and cross section information. This technique should be used as a guide for establishing a normal pool elevation.

To begin with, information is tablulated by 3-foot increments. Why 3 feet? Because emergent vegetation will occupy the area at 0 to 3 feet below normal pool, and the area greater than 3 feet below normal pool will be for the most part open water. Other research recommends that the ratio of vegetation to water area be kept between 30 and 70 percent with 50 percent an optimum. Our studies show that emergents in stable water die out below 2 feet, but water levels in impoundments will naturally fluctuate 1-foot below normal pool so that a 3-foot increment typically reflects the emergent zone in most impoundments. If an area is likely to have a strong groundwater source and thus a stable water elevation, use a 2-foot increment. Where there are floating mats water depth is not critical. Interspersion will be determined by the total impoundment area and the mat area.

Figure 4 shows that open water area (63 percent) (emergent vegetation area 37 percent), and total impoundment area (88 acres) are optimized and maximized respectively at a normal pool elevation of 90 feet. Actual normal pool elevation was set at 89 feet to allow for sufficient free board and to protect adjacent road beds.

TOP ELEVATION (FT.)	3-FOOT INCREMENT (FT.)	AREA BETWEEN UPPER & LOWER INCREMENT ELEV. (ACRES)	AREA BELOW THE LOWER INCREMENT ELEV. (ACRES)	TOTAL AREA AT THE TOP ELEV. (ACRES)	ESTIMATED PERCENT OPEN WATER (%)
84	81-84	2.5	0.5	3.0	20
85	82-85	11.0	0.5	11.5	4
86	83-86	30.0	1.0	31.0	3
87	84-87	52.0	3.0	55.0	5
88	85-88	53.5	11.5	65.0	18
89	86-89	46.0	31.0	77.0	40
90	87-90	33.0	55.0	88.0	63

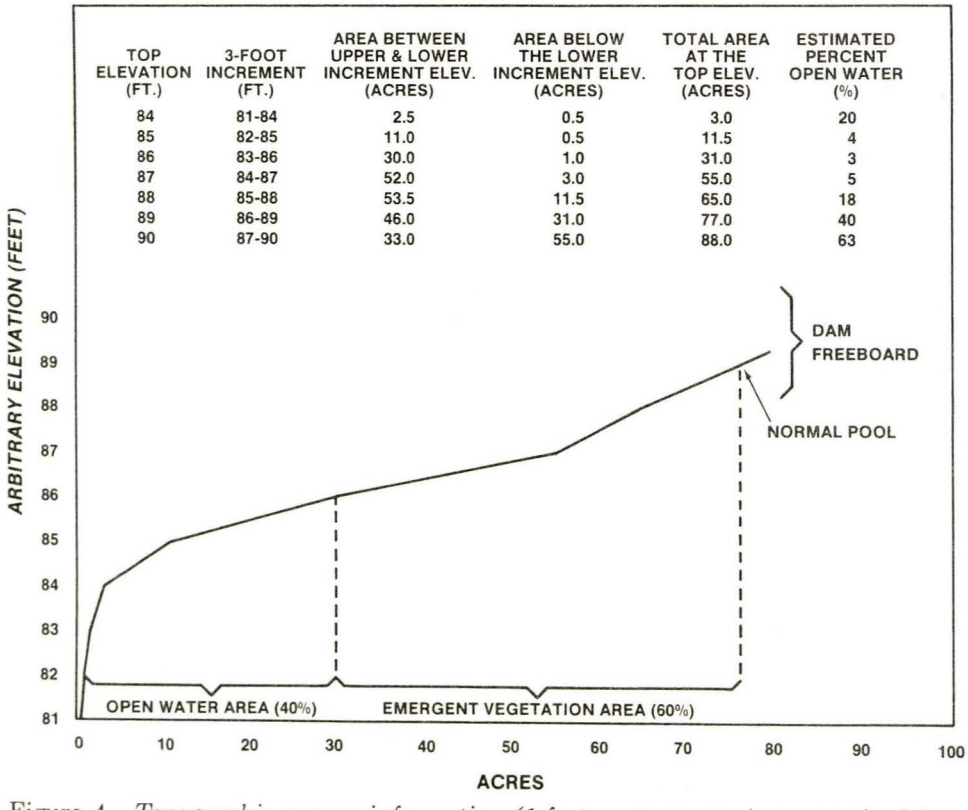

Figure 4.--*Topographic survey information (1-foot contour map) summarized for Bear Brook Impoundment on the Chippewa National Forest.*

VEGETATION MANAGEMENT IN WATER IMPOUNDMENTS: WATER-LEVEL CONTROL

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Within a physiographic region, the soil water regime is the most significant environmental factor determining what plant species will occupy a particular site. There are a variety of factors that contribute to soil water regimes, among them are topography, soil materials, watershed size (Verry 1983), and climate. Various measures of these factors were used to develop a key to opportunities for controlling water level for impoundments or impoundment sites according to their potential for wildlife habitat management. The key sets limits on prescriptions, determining what specific habitat management objectives are reasonable.

An existing impoundment or a potential impoundment site is first examined for special conditions. These are deep organic soils, and the presence or potential development of extensive floating vegetation mats which, for the most part, resist control by water-level manipulation. Impoundments without special conditions are then examined with respect to the difficulty expected in maintaining a water-level prescription. The difficulty is a function of water supply dependability and the expense in time and equipment necessary to insure that the water-level is held at the prescribed level.

While selecting impoundment sites it is not necessarily wise to automatically rule out a site simply because precise water-level management prescriptions are unlikely to succeed. Even unmanageable impoundments offer diversity to a management unit that may not be achieved in any other way. It simply isn't practical to expect all impoundments to mirror each other, or to be managed with some central image as the goal. If the goal is to maximize habitat diversity throughout a management unit, then these impoundments may also have their place.

When an impoundment is considered suitable for water-level management, the prescription may require either cyclic or non-cyclic drawdowns. Cyclic drawdowns call for a repeating water-level regime that may require 5 or more years to complete, but does not require a regular on-site evaluation before each action. Non-cyclic drawdowns require a regular on-site evaluation and identification of need before each action. Drawdowns may be either partial or full. A partial drawdown is anything short of lowering the water level to the lowest elevation permitted by the structure. Similarly, a full drawdown lowers the water level to the lowest possible elevation. Both types of drawdown may vary in frequency, starting date, and duration. Drawdowns are made with reference to normal pool--the preferred height (elevation) of the water surface when the impoundment is considered full (fig. 1). Judicious prescriptions will permit the concentration of effort where it will be most beneficial and will include the objective and the criterion for judging success.

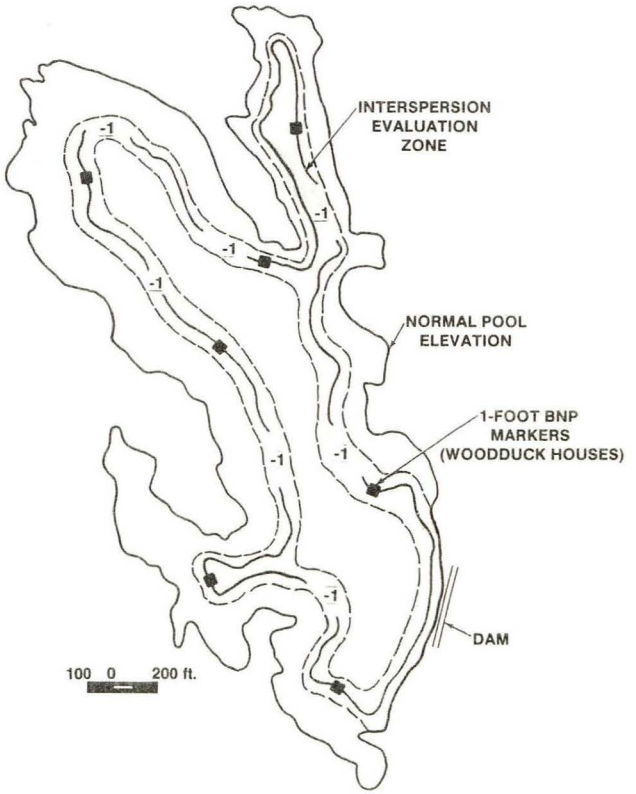

Figure 1.--*Impoundment overview illustrating the location of an interspersion evaluation zone centered on 1-foot BNP.*

The common goal in constructing and managing wildlife water-impoundments is to create and maintain deep marsh habitat primarily for producing waterfowl. Other wildlife are important, but priority is given to waterfowl. For effective waterfowl production the water level must be maintained at normal pool during nesting and brood rearing. During periods of drawdown an impoundment is obviously not ideal for production so there may be a tendency to minimize drawdown time without giving adequate consideration to whether or not drawdown objectives have been achieved. Under these circumstances drawdowns are viewed as "a means-to-an-end" with little value being placed on the drawndown habitat. Unfortunately, this view overlooks the importance of mud flats to a variety of shore birds and other animals that thrive in this environment. The point is, drawdowns should not be viewed as a necessary evil; they are valuable in and of themselves and there should be no reluctance to continue a drawdown through whatever time is required to achieve the desired change in the normal pool habitat. This may require more than 1 year of full drawdown to cause the desired change.

This chapter describes the response of wetland plant communities to water regimes that may or may not be subject to prescriptions. It is based primarily on the results of research conducted by the author in north-central Minnesota. However, visits to wetlands across the northern Lake States indicate that the principles discussed are generally applicable.

The following discussion is directed at understanding the physical and biological limitations that determine the outcome of a drawdown prescription rather than writing a universal prescription. With that understanding the biologist will be better prepared to write prescriptions that meet the somewhat unique properties of each impoundment.

A KEY TO OPPORTUNITIES FOR CONTROLLING WATER LEVEL

1. Mineral soil; or fibric (least decomposed) organic soils $\leq$ 6 inches thick; no extensive floating mats of organic soil and vegetation 3
   1. Organic soil, extensive, and > 6 inches thick; or extensive floating mats of organic soil and vegetation 2
2. Surface fibric (least decomposed) organic soil > 6 inches thick without an underling hemic (moderately decomposed) and/or sapric (most decomposed) layer that is > 1-foot thick; or extensive floating mats of organic soil and vegetation present ..... Class A-1
   2. Hemic (moderately decomposed) of sapric (most decomposed) organic soil > 1-foot thick that may underlay fibric (least decomposed) surface layers (may be 6 feet or deeper) ..... Class A-2
3. Soils not strongly calcareous in upper foot 5
   3. Soils strongly calcareous in upper foot ..... 4[1]
4. Watershed area/impoundment area $\leq$ 0.75 $\times$ map value[2] ..... Don't build
   4. Watershed area/impoundment area > 0.75 but $\leq$ 1.5 $\times$ map value ..... Class B-1
   4. Watershed area/impoundment area > 1.5 but $\leq$ 3 $\times$ map value[2] ..... Class B-2
   4. Watershed area/impoundment area $\leq$ 3 $\times$ map value[2] ..... Class B-3
5. Watershed area/impoundment area $\leq$ 0.75 $\times$ map value[2] or specific conductance $\leq$ 25 micro mhos/cm ..... Don't build
   5. Watershed area/impoundment area > 0.75 $\times$ map value[2] or specific conductance > 25 micro mhos/cm 6
6. Specific conductance $\leq$ 100 micro mhos/cm ..... Class B-1
   6. Specific conductance > 100 micro mhos/cm 7
7. Watershed area/impoundment area $\leq$ 3 $\times$ map value[2] ..... Class B-2
   7.Watershed area/impoundment area > 3 $\times$ map value ..... Class B-3

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[1]*An estimate of impoundment management class before construction is tentative because the presence of calcareous material precludes the use of specific conductance for identification of water source and amount. Experience after construction may lead to a change in management class.*

[2]*See Verry 1983 (fig. 3)*

VEGETATION CLASSIFICATION

Plant species with the potential to occupy wetland sites throughout the Lake States are far too numerous for individual consideration in management schemes. In most cases we simply don't know enough about each species to successfully manage them intensively. The alternative is extensive management wherein they are classified according to similarity of growth form and habit. These groups are commonly referred to as life-forms as described by Golet and Larson (1974). The classification scheme used in this manuscript, and the assignment of species present in northern Minnesota, is summarized in the Appendix. The list is generally applicable across the forested region of the western Great Lakes.

Classification of whole wetlands typically depends on the composition and distribution of vegetation. The most widely known wetland classification system with wildlife management emphasis was developed by Shaw and Fredine (1956). A brief summary of their pertinent Wetland Types is presented in table 1, (Verry 1983) with a cross reference to a latter system developed by Cowardin *et al.* (1979). The Shaw and Fredine system will be used in the following discussion.

WHEN SHOULD AN IMPOUNDMENT BE DRAWN DOWN?

Management objectives will determine the appropriate drawdown prescription for impoundments. Typical objectives are:

1. Improve or maintain waterfowl nesting and brood habitat,
2. Improve or maintain availability of food plants for transient waterfowl,
3. Improve, maintain, or reduce fish or fur-bearer habitat, or
4. simply maximize productivity and diversity of a management area.

The biologist must determine what prescription will be used to achieve specified objectives. There is no one prescription that can be applied universally but there are general principles associated with drawdowns that must be considered in preparing prescriptions. These principles are discussed in section V as they relate to various impoundment management classes.

Let's assume that the first objective listed above is to guide the preparation of a drawdown prescription for a management area consisting of several impoundments. The habitat of each impoundment should first be examined. In a simplistic examination, the potential spectrum of principle wetland habitat components

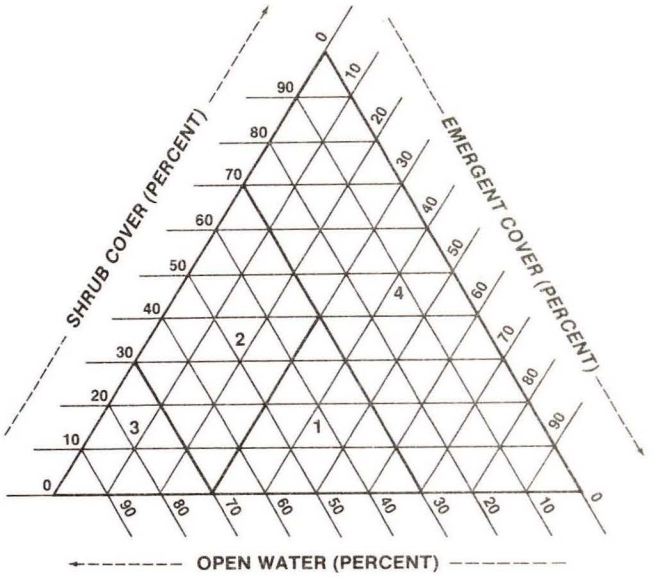

Figure 2.--*Potential interspersion of shrubs, emergents, and open water based on percent cover at the 1-foot below normal pool elevation. Four interspersion conditions are recognized.*
1. Good interspersion of vegetation and water,
2. Fair interspersion with shrubs dominate,
3. Poor interspersion--too much open water, and
4. Poor interspersion--too little open water.

(shrubs, emergents, open water) can be integrated as seen in figure 2. Each is expressed as a percent of total cover in a triangular grid. Percent cover must be estimated visually during a visit to each impoundment. The zone centered at 1 foot below normal pool elevation (1-foot BNP) is the key zone for this estimate. Make the estimate with the water level at normal pool, and no earlier than July 15 each year. An aerial survey with a small aircraft is probably the least expensive method. Permanent markers should be established in each wetland for identification of the 1-foot BNP zone. A series of wood duck houses at this elevation would make ideal markers.

Each impoundment may be located within the grid to illustrate its position with respect to four conditions of vegetation interspersion. These are:

Condition 1--good interspersion of vegetation and open water,
Condition 2--fair interspersion but shrubs dominate at the expense of emergents,
Condition 3--poor interspersion--too much open water, and
Condition 4--poor interspersion--not enough open water.

When waterfowl are the focus, the impoundment should be maintained in Condition 1. If an impoundment is judged to be in either of the other conditions,

then a drawdown should be prescribed to alter the habitat accordingly. Plotting the progress of an impoundment through several years will provide a valuable record of the prescription success and will guide the process of updating the prescription. Prescriptions must be dynamic to accommodate the unexpected events that inevitably occur and that alter the condition of an impoundment.

Although the habitat condition grid in figure 2 may be used for guiding the management of specific impoundments, its greatest utility may be in the simultaneous evaluation of any number of impoundments within a management area. By plotting several impoundments on the same grid, the manager can quickly evaluate the overall habitat condition. The least desirable would be to have the majority of the impoundments clustered within either Condition 2, 3, or 4. This may indicate a general problem in achieving management goals. If the majority are close to or within Condition 1 then the idealized goal is being achieved and prescriptions are on track.

WATER-IMPOUNDMENT MANAGEMENT TYPES AND OPTIONS

The KEY TO OPPORTUNITIES FOR CONTROLLING WATER LEVEL may be used to direct the user to particular impoundment management classes described in this section, or the section may be read in its entirety for an overview of the management options available for impoundments in the western Great Lakes. The management strategy favored by the author would have several impoundments within an administrative land unit, be it a national forest, state forest, refuge, etc., with the goal being to maximize wildlife habitat diversity throughout the unit. The manager needs to identify deficient wetland habitat types; or identify opportunities to convert to more productive sites when a specific form of wildlife is to be favored (Verry 1983).

Class A-1.--Extensive Floating Mats

When a surface organic soil horizon exceeds 6 inches in thickness and is vegetated by non-woody plants (ericacous shrubs may be an exception), raising the water level by impounding water will very likely result in a floating mat. Existing plant roots bind the mat together but apparently do not anchor it to mineral soil. Apparently, a cleavage develops between the root mass and underlying less consolidated organic material or the mineral layer, permitting the mat to float up with the rising water level. Under pre-impoundment conditions these sites are typically wet as evidenced by the presence of the original organic soil. Therefore, the mat will persist during subsequent drawdown with little or no change and will simply float again when the water level returns to normal pool. Obviously, water-level manipulation is an ineffective management technique for floating mats and these wetlands will persist as Type 2 inland fresh meadows. Mats cause an additional problem if sections break away from the main mat and plug the spillway. This may result in excessive high water and unwanted flooding which may also pose a risk to the structure.

Impoundments with floating mats are not necessarily undesirable; in fact, during the early years after impoundment they may be exceptionally productive. The key will be good interspersion of open water (not less than 30 percent of an area) and floating mat as described in the previous section. When a potential exists for extensive continuous mats to begin floating immediately after construction, the impoundment should be considered a questionable venture because its effective life may be very short. On the other hand, impoundments with only localized development of sedge mats may be desirable because of the diversity that they can add within a wetland.

Organic soils with trees and tall shrubs do not usually float when newly flooded. These communities change dramatically during initial flooding because the woody plants are killed. All trees native to the Lake States are adversely affected. Speckled alder, a large common shrub, is also sensitive to flooding and will be killed. Willows, although somewhat more tolerant of flooding is continuous through the growing season (Knighton 1981). Organic soils supporting ericaceous shrubs may float with little diverse effect on the shrubs.

Willow survival can be encouraged by regular partial drawdowns that provide a minimum of 6 inches of drained soil[3]. Drawdowns should be made no later than July 15 to ensure healthy shrub growth. Speckled alder also can benefit from partial drawdowns if the drawdown occurs before June 15, but this seriously limits the time at normal pool, a critical factor in waterfowl brood management.

Class A-2--Protection Against Erosion of Deep Peats

Flooded peats (over 6 inches thick) around the edges of large multi-purpose impoundments (1,000-acres-plus size) can be subject to severe erosion[4]. The problem arises on areas receiving large spring runoff (> 1,000 cubic feet per second) if the impoundment is held

[3]*Data on file at the Forestry Science Laboratory, North Central Forest Experiment Station, Grand Rapids, MN.*

[4]*Personal communication from Arlyn Linde, Wisconsin DNR, Oshkosh, WI.*

at normal pool over winter, Then, if ice freezes deep enough to grab plant roots and the organic soil, spring flows will lift 6 inches or so of soil with the ice, pulverize it with wind-pushed ice, and flush it out in overflow. This annually deepens the shallow wildlife zone around an impoundment edge. In this situation erosion can be prevented by drawing water down during the winter. Begin drawdowns after 3 inches of ice has formed and achieve a water-level drop of 2 to 3 feet. This provides for spring flood retention, but it also leaves a collapsed layer of 3 inches of ice on the top of the shallow areas with organic soil. These "mud flats" will melt out in the spring prior to the snowmelt peak flow. Starting drawdown with 3 inches of ice protects muskrat populations, otherwise drawdowns can start after the waterfowl season ends.

Continue with step 3 in the key to determine the dependability of water supply.

B-1. Inadequate Water Supply

An inadequate water supply limits the management potential of these wetlands but does not exclude them from being desirable components of the habitat. However, they will revert to inland fresh meadows (Type 2) or inland shallow marshes (Type 3) during the growing season in normal and dryer than normal years despite drawdown prescriptions. In wetter than normal years they will remain flooded, approximating an inland deep marsh (Type 4). Water level management efforts will be most effective if directed at maintaining water levels as near to normal pool as possible. Normal weather fluctuations will provide sufficiently frequent natural full and partial drawdowns to usually eliminate the need for planned drawdowns. A prescription of cyclic drawdowns (every 5 years) will simply leave these impoundments dry or in low water for too long. In the event of several consecutive wet years a planned drawdown might be desirable if a need to adjust the habitat has been identified. The manager must realize that refilling an impoundment in Class B-1 is dependent on precipitation and not just the replacement of stop logs in the outflow structure. The response of wetland vegetation to drawdown in three impoundments on the Chippewa National Forest that had inadequate water supplies were studied for 4 years (Knighton 1982). Weather-caused drawdowns of varying duration and frequency were observed. The following discussion of what can be expected in similar impoundments is based on those studies.

Meadow emergents (See Appendix, table 3) will be the prevailing plants at elevations near normal pool. Their expected distribution is illustrated in figure 3 for high and low water years. Their peak biomass will occur at about 1 foot below normal pool but will shift downward an additional foot and increase during low water years. These emergents are perennials, [primarily sedges (*Carex* spp. L)] and a variety of grasses that persist to some extent even during extended flooding. When the water level is dropped, meadow emergents will expand vegetatively and quickly occupy the site. Two years of exposed soils or at least intermittently exposed soils will be needed for invasion from seed assuming that a viable seed supply exists.

Mudflat emergents (See Appendix, table 3) are also a very important component of the vegetation in these impoundments. Their biomass will show extreme fluctuations from high to low water years and they will be particularly prevalent during drawdown at 2- and 3-feet BNP where competition with meadow emergents is lessened by previous flooding (fig. 3). Mudflat

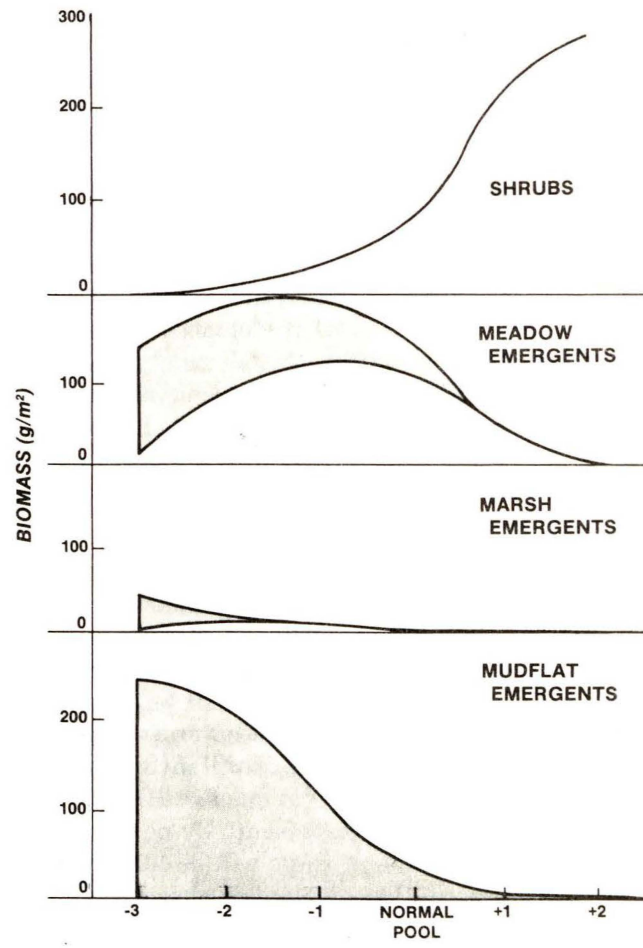

Figure 3.--*Effects of drawdown and normal pool water levels on shrub and emergent biomass distribution in impoundments having an inadequate water supply for precise water-level management (Class B-1 impoundments). For emergents the upper line approximates biomass distribution during full drawdown and the lower line approximates biomass when the water level is near normal pool throughout the year.*

emergents are typically annuals or biennials that require moist, unvegetated soils for successful germination and growth to maturity. To a very limited extent, the biennials are able to persist into their second year even if water levels increase. They are prolific seed bearers, but the seeds apparently lose their viability if flooded continuously for several years. Several are successful late season germinators, particularly the biennials, and will establish even if water levels remain high until late summer. Maturity is most successful if in the following year water levels remain low.

Typically, mudflat emergents are sensitive to flooding and disappear quickly when water levels rise. They must be considered transient but their seeds provide valuable wildlife food and when dead they offer an ideal environment for many invertebrates that feed on micro-organisms that are active on decaying tissue.

Marsh emergents have difficulty surviving through several years given fluctuating wet-dry conditions that prevail in impoundments with inadequate water. They are typically perennials (Appendix, table 3), and require more stable water regimes. During the wettest years they will be most abundant at an elevation about 1 foot BNP (fig. 3), but will represent only 2 percent of the total herbaceous biomass. During years of low water they will appear at lower elevations in a manner paralleling that of invading mudflat emergents but will represent only 10 percent of the combined biomass. Subsequent reflooding will quickly eliminate any gains that accrue during low water. Even short term flooding of two to three feet will severely limit their distribution. As long as the ideal water depth for marsh emergents is continually shifting within an impoundment their success will be limited.

Floating-leaved and submergent vegetation (Appendix, table 4) will be limited to areas where pools persist. Submergents may be dense (> 300 g/m^2) in residual pools during low water at elevations 3 or mmore feet BNP. And they can invade at higher elevations as the water level moves up during wet periods. Widely scattered individuals will invade and the biomass will be low, < 60 g/m^2 at one foot BNP. Floating-leaved vegetation will be essentially non-existent regardless of elevation and there will be little opportunity to increase this life-form in the absence of more stable water-levels.

In the event that a series of consecutive wet years occurs, submergents may become locally dense. A drawdown will dramatically reduce the biomass the first year of reflooding but subsequent reinvasion should be expected if consecutive wet years occur.

These impoundments will have a shrub perimeter that is most developed at 2-feet above normal pool elevation. At and below normal pool shrubs will be essentially absent. Willows and alder will prevail. Willows tend to be a little more resistant to continuous flooding through the growing season than alders and even resprout vigorously after a period of high water that has left the aerial parts obviously dead. As indicated earlier, the typical water regime in impoundments with an unmanageable water supply favors meadow emergent vegetation at elevations below normal pool. These emergents are very effective at competing with shrubs and contribute to their exclusion (fig. 3). Emergent recovery after flooding is much quicker than shrubs, contributing to their competitive edge.

B-2.--Adequate Water Supply; Prescriptions are Least Difficult to Apply

These impoundments have adequate water for water-level management and are likely to be most successful. The reason is simple--the water supply is moderate and therefore more easily maintained near the desired level. The key is replacement-time, or the time required on the average for a complete exchange of water during the growing season. For these impoundments the replacement-time is measured in weeks; for example, if beaver are actively damming the outlet, a visit to remove the dam every week is adequate. Impoundments with replacement-times measured in days require almost daily visits to prevent flooding when beaver are active (in the forested region of the Lake States it's always safe to assume that beaver will be active in all impoundments). Given an adequate water supply beaver are the single most important factor in the failure to meet a water-level prescription. Methods of minimizing beaver problems are discussed by Buech (1983).

Even with precise control, water-level manipulation is frequently over-rated as an effective wetland habitat management tool. Other factors (Phillips 1970) such as the degree of substrate drainage during drawdown, the amount of surface soil relief throughout the wetland, and substrate composition are more important in determining interspersion of vegetation than is water-level manipulation, *per se.* Soil relief, or the degree of irregularity in the soil surface will strongly influence the degree of interspersion of vegetation and open water that will exist. Basins with a uniform soil surface will develop monotonous vegetation despite planned drawdowns because the soil water regime will be essentially the same over extensive contiguous areas. Typically, plants will segregate into concentric zones limiting interspersion to one dimension. Drawdowns will shift the zones up and down the slope but any mixing of zones is very short lived. If the zones are interrupted by localized irregularities in the soil

surface, then lasting interspersion of vegetation on a second dimension will exist.

Monotonous basins are particularly prevalent in the western Great Lakes region because the climate favors peat formations. Localized irregularities in the mineral soil surface within basins have largely been flattened out by peat accumulation. Interspersion can be substantially enhanced by extensive scraping and piling of soil to form small islands along the original 1-foot-below-normal-pool contour. Although water-level manipulation may be simpler to implement then forming islands, it is by no means as effective.

The response of wetland vegetation to drawdown in two impoundments of Class B-2 on the Chippewa National Forest was studied for 4 years (Knighton 1982). The drawdowns were started in late summer and lasted through the next growing season. The impoundments were about 3 and 4 years old when the study began and the drawdowns were applied during the study at 5 years of age. The prescription was the same uniform 5-year drawdown cycle that has been applied to all impoundments on the Chippewa until recently. It includes an annual partial drawdown about 1 foot, beginning in late summer. The purpose of the partial drawdown has been to encourage shrub growth at elevations below normal pool. The results lead to the following generalizations about 5-year cycles.

Drawdowns will sharply increase emergent plant biomass at depths from normal pool down to 3-feet BNP. The sharpest increase will be at 3 feet where emergents are essentially non-existent prior to drawdown (fig. 4). The increase in emergents will be shortlived, disappearing during the first year after drawdown. The long term response of emergent plant biomass to this drawdown prescription (for the elevation 1-foot BNP) is characterized by sharp peaks and low stable valleys but essentially no lasting change in vegetation biomass persists between drawdowns (fig. 5). The effects of this drawdown prescription on plant species composition follows an identical pattern to that of biomass. There is simply very little lasting change, if any. The prevailing view--that changes in vegetation brought about by drawdown only slowly disappeared over several years--simply does not materialize here. The result is that there are three habitat conditions associated with a cyclic drawdown prescription. They are:

1. Large quantities of emergent biomass and some change in emergent composition during drawdown,
2. Large quantities of dead emergent biomass submerged and decaying during the first year after drawdown, and
3. Small quantities of living and dead emergent biomass during all other years.

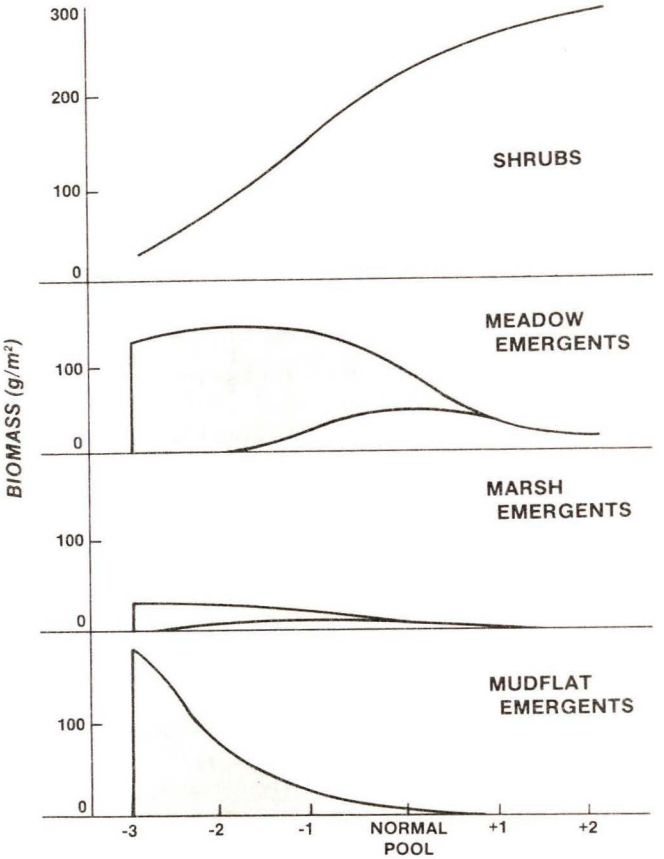

Figure 4.--*Effects of drawdown and normal pool water levels on shrub and emergent biomass distribution in impoundments where water-level management is least difficult (Class B-2 impoundments). For emergents the upper line approximates biomass distribution during full drawdown and the lower line approximates biomass when the water level is near normal pool throughout the year.*

In general, the response of particular plant lifeforms to drawdown will follow the same patterns described for impoundments that were unmanageable because of an inadequate water supply (B-1). There will be some differences that warrant consideration and they will be discussed with reference to the above mentioned section.

Meadow emergents (See Appendix, table 3) will be the prevailing emergent plant but the biomass will be only 20 percent of that found at 1-foot BNP in B-1 impoundments during normal pool years. The difference will be even greater at lower elevations (fig. 4). The low plant productivity is due to more stable water levels during the growing season and this despite partial annual drawdowns that may be applied the last half of each summer. During drawdown the biomass increase will actually be greater but the total will still be about 70 percent of that in B-1 impoundments at

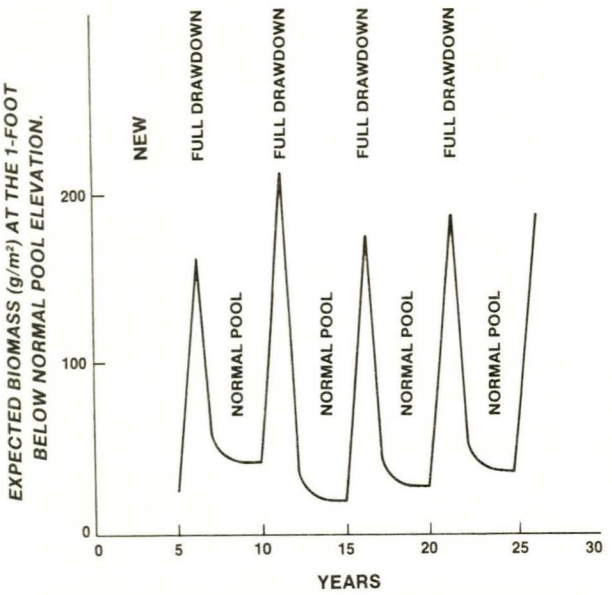

Figure 5.--*Expected response of emergent plant biomass to a full drawdown at 5 year intervals in impoundments that are least difficult to manage (Class B-2). The curves are generalized and extrapolated from 4 years of study on two impoundments.*

1-foot BNP. During normal pool years meadow emergents will be insignificant at elevations lower than 1-foot BNP.

Marsh emergents (See Appendix, table 3) will have a very limited distribution in B-2 impoundments. They will increase somewhat during drawdown but disappear with reflooding (fig. 4). They will be excluded from their most favorable water depth (normal pool down to 1-foot BNP) by partial annual drawdowns. They simply can't survive the late summer drawdown above 1-foot BNP and they are eliminated by early season deep flooding at lower elevations. They will be favored only by full-year stable water levels for several consecutive years.

Mudflat emergents (see Appendix, table 3) will be absent during normal pool years and increase somewhat during drawdown (fig. 4). At 1-foot BNP they will invade with only 20 percent of the invasion biomass of B-1 impoundments. At 3-feet BNP they will invade at 70 percent of B-1 biomass. Why mudflat emergents are less successful invaders in B-2 impoundments isn't clear but there is reason to expect that fewer viable seeds are present, particularly at lower elevations where flooding is more persistent. Also, drawdowns are less frequent, or occur later in the season in the case of partial drawdowns, and seed production is therefore less dependable.

Floating-leaved (Appendix, table 4) plant biomass will occur as a trace < 1 percent) at 3-feet BNP during normal pool years. These plants are typically slow to establish themselves and are very sensitive to drawdown or competition with emergents. They will have very limited success in impoundments receiving full drawdowns at 5-year intervals or less.

Submergents (Appendix, table 4) will dominate (90 percent) the herbaceous biomass at 3-feet BNP and lower elevations during normal pool years. Their importance will decrease rapidly as water level increases and will represent only 4 percent of the herbaceous biomass at 1-foot BNP.

Shrub biomass (predominately willows) will occur at all elevations below normal pool (fig. 4). The biomass at 1-foot BNP will be about 150 g/m^2 or 50-60 percent of the shrub biomass at 2-feet *above* normal pool. From there it will drop off to 25 g/m at 3-feet BNP. This is substantially more shrub biomass than will be found in B-1 impoundments where water levels decline progressively through the summer and is attributed to effects of partial annual drawdowns combined with the reduced competition with meadow emergents that occurs when the water level is held at normal pool during the first half of the growing season. Partial drawdowns should begin no later than July 15 to assure that willows will remain healthy. If alders are wanted, partial drawdowns must begin no later than June 15 at the latest.

As previously stated, the number of years between full drawdowns has little lasting effect on impoundment vegetation. On the other hand, drawdowns lasting more than 1 year will increase the biomass of meadow emergent vegetation present at the end of a drawdown. In impoundments where meadow emergent biomass is insufficient at 1-foot BNP, 2 consecutive years of drawdown will be needed for it to increase substantially.

B-3 Adequate Water Supply; Prescriptions are Most Difficult to Apply

The response of these impoundments to various water level regimes is very similar to that discussed for management type B-2 impoundments. The difference is in the amount of time and energy that must be expended by field personnel to assure that water levels meet the prescription. These impoundments have water replacement times measured in days and therefore require almost daily visits to assure success. If the impoundments are not checked frequently for beaver damming, the animals will probably control the water level despite special structures intended to thwart their dam building efforts. Buech (1983) suggests some structures that may prove more effective.

CATTAIL IN WATER IMPOUNDMENTS

Cattail, a robust emergent, frequently will encroach on other wetland vegetation and become dominant. Found everywhere, it annually produces large quantities of biomass in monotypic communities. Because of its prevalence it is probably our most thoroughly studied wetland plant genus and specific practices have been proposed for its management and control (Beule 1979). Desirability of a cattail community will depend on its stem density and interspersion with other vegetation and open water, and the wildlife that are to be favored.

Broad-leaf cattail was either already established in all of my study impoundments at the beginning, or it became established during the 4 year course of the study. In any event, its distribution within impoundments definitely increased, apparently irrespective of management on the impoundment. Conditions that most favor encroachment and the effects of drawdown were observed.

Cattail invasion by seed will occur on mineral soil that remains poorly drained during drawdown and that already has very little sedge or grass to compete. Once established, cattail will endure several years of continuous flooding while expanding vegetatively. Drawdowns will only reduce cattail populations if the soil is permitted to drain thoroughly within the rooting zone. Persistent rainfall, heavy textured soils, or both will reduce the effectiveness of drawdowns. Two or more years may be needed for a suitable kill.

The presence of an organic soil suggests inherent poor drainage so that opportunities for cattail management by drawdown are very limited. Cattail will become established on an exposed organic soil as readily as on mineral soil when it does not have to compete with established sedge or grass. Typically, sites having an organic soil will not drain adequately to dry out the soil unless major changes are made in local drainage patterns. During drawdown cattail will flourish on wet soils rather than die out, and at normal pool it will do well when flooding depth is less than 2 feet. Other methods of control must therefore be used.

Floating cattail mats have been observed to rise 4 to 5 feet in the deeper areas of impoundments and then to subside with the water level during breakdown. The shoreweed edges of the floating mats can be repeatedly trimmed to the area of the persistently saturated substrate by using full drawdowns lasting at least through one growing season. Drawdowns therefore may be used to limit the expansion of floating cattail mats to some extent but they will not eliminate them or significantly alter stem density throughout the poorly drained areas of an impoundment.

LITERATURE CITED

Beule, John D. Control and management of cattails in southeastern Wisconsin wetlands. Tech. Bull. 12. Madison, WI: Department of Natural Resources; 1979. 40 p.

Buech, Richard R. Beaver in water impoundments: understanding a problem of water-level management. In: Water impoundments for wildlife: a habitat management workshop. Gen. Tech. Rep. NC-100. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1985: 95-105.

Cowardin, Lewis M.; Carter, Virginia; Golet, Francis C.; LaRoe, Edward T. Classification of wetlands and deepwater habitats of the United States. FWS 10BS-79/31. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service, Office of Biological Services; 1979. 103 p.

Golet, Frances C.; Larson, Joseph S. Classification of freshwater wetlands in the glaciated northeast. Res. Publ. 116. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife; 1974. 56 p.

Knighton, M. Dean. Growth response of speckled alder and willow to depth of flooding. Res. Pap. NC-198. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1981. 6 p.

Knighton, M. Dean. Vegetation dynamics in wildlife water-impoundments in north central Minnesota. St. Paul, MN: University of Minnesota; 1982. 182 p. Dissertation.

Phillips, John. Wisconsin's wetland soils: a review. Res. Rep. 57. Madison, WI: Department of Natural Resources; 1970. 27 p.

Shaw, Samuel P.; Fredine, Gordon. Wetlands of the United States, their extent and their value to waterfowl and other wildlife. Circular 39. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service; 1956. 67 p.

Verry, Elon S. Selection of water impoundment sites in the Lake States. In: Water impoundments for wildlife: a habitat management workshop. Gen. Tech. Rep. NC-100. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1985: 31-38.

APPENDIX

Table 1.--*Species assignment to the tree life-forms*

Life-form and scientific name	Common name
TREES	
Live deciduous	
Acer saccharum Marsh.	Sugar maple
A. spicatum Lam.	Mountain maple
A. rubrum L.	Red maple
Betula papyrifera Marsh.	White birch
Fraxinus nigra Marsh.	Black ash
Populus grandidentata Michx.	Bigtooth aspen
P. balsamifera L.	Balsam poplar
P. tremuloides Michx.	Quaking aspen
Prunus pensylvanica L.f.	Pin cherry
P. virginiana L.	Choke cherry
P. serotina Ehrh.	Black cherry
Quercus alba L.	White oak
Q. borealis Michx. f.	Red oak
Q. macrocarpa Michx.	Burr oak
Q. ellipsoidalis E.J. Hill.	Scarlet oak
Tilia americana L.	Basswood
Ulmus americana L.	American elm
U. rubra Muhl.	Slippery elm
Live evergreen	
Abies balsamea (L.) Mill.	Balsam fir
Picea glauca (Moench) Voss.	White spruce
P. mariana (Mill.) BSP	Black spruce
Pinus strobus L.	White pine
P. banksiana Lamb.	Jack pine
P. resinosa Ait.	Red pine
Thuja occidentalis L.	N. white cedar

Table 2.--*Species assignment to the shrub life-forms*

Life-form and scientific name	Common name
SHRUBS	
Tall slender	
Alnus rugosa (DuRoi) Spreng.	Speckled alder
Amelanchier spp. Medic.	Service berry
Ostrya virginiana (Mill.) K. Koch	Ironwood
Bushy	
Cornus stolonifera Michx.	Red-osier dogwood
Diervilla lonicera Mill.	Bush honeysuckle
Lonicera spp. L.	Honey-suckle
Salix spp. L.	Willow
Viburnum Rafinesquianum Schult.	Downy arrowwood
V. opulus L.	High-bush cranberry
V. lentago L.	Sheepberry
Low compact	
Arctostaphylos uva-ursi (L.) Spreng.	Bearberry
Chamaedaphne calyculata (L.) Moench.	Leather-leaf
Gaultheria procumbens L.	Wintergreen
Ledum groenlandicum Oeder.	Labrador tea
Vaccinium myrtilloides Michx.	Blueberry
V. angustifolium Ait.	Blueberry
Low sparse	
Corylus americana Walt.	Hazel
C. cornuta Marsh.	Beaked hazel
Rhamnus alnifolius L'Her.	Buckthorn
Ribes spp. L.	Gooseberry
Rosa spp. L.	Wild rose
Rubus spp. L.	Blackberry
Spiraea spp. L.	Spirea

Table 3.--*Species assignment to the emergent life-forms*

Life-form and scientific name	Common name
EMERGENTS	
Mudflat	
Alisma plantago-aquatica L.	Water plantain
Alopercurus aequalis Sobol.	Foxtail
Bidens spp. L.	Begger-ticks
Chenopodium album L.	Lamb's quarters
Cicuta maculata L.	Water hemlock
C. bulbifera L.	Water hemlock
Epilobium adenocaulon Haussk.	Willow-herb
Erechtites hieracifolia (L.) Raf.	Fireweed
Eupatorium maculatum L.	Joe-Pye weed
E. perfoliatum L.	Boneset
Galium spp. L.	Bedstraw
Geum spp. L.	Avens
Impatiens biflora Willd.	Jewelweed
Laportea canadensis (L.) Gaud.	Wood nettle
Lycopus uniflorus Michx.	Bugle-weed
L. americanus Muhl.	Bugle-weed
Melampyrum lineare Desr.	Cowwheat
Mentha arvensis L.	Mint
Mimulus ringens L.	Monkey-flower
Naumburgia thyrisiflora (L.) Duby.	Tufted loosestrife
Polygonum cilinode Michx.	Bindweed
P. lapathifolium L.	Smartweed
P. sagittatum L.	Smartweed
P. punctatum Ell.	Smartweed
Potentilla spp. L.	Cinquefoil
Rorippa islandica (Oeder) Borbas.	Yellow cress
Rumex spp. L.	Dock
Scutellaria galericulata L.	Skullcap
S. lateriflora L.	Skullcap
Solidago spp. L.	Goldenrod
Stachys palustris L.	Hedge hettle
Triadenum virginicum (L.) Raf.	Marsh St. John's-wort
Urtica dioica L.	Nettle
Robust	
Phragmites communis Trin.	Reed
Typha latifolia L.	Broad-leaf cattail

(Table 3--continued)

(Table 3--continued)

Life-form and scientific name	Common name
Tall meadow	
Acorus calamus L.	Sweet flag
Iris versicolor L.	Blue flag
Phalaris arundinacea L.	Reed Canary grass
Zizania aquatica L.	Wild rice
Short meadow	
Carex spp. L.	Sedge
Dulichium arundinaceum (L.) Britt.	Three-way sedge
Gramineae	Grass
Argrostis spp. L.	Bent Grass
Calamagrostis spp. Adans.	Bluejoint
Leersia oryzoides (L.) Sw.	Cut-grass
Oryzopsis spp. Michx.	Rice grass
Poa spp. L.	Wild rice
Juncus spp. L.	Rush
Narrow-leaved marsh	
Eleocharis spp. R. Br.	Spike rush
Equisetum sylvaticum L.	Horsetail
E. palustre L.	Horsetail
E. fluviatile L.	Horsetail
Scirpus validus Vahl.	Great bulrush
S. subterminalis Torr.	Bulrush
S. americanus Pers.	Bulrush
Scirpus spp. L.	Bulrush
S. cyperinus (L.) Kunth.	Wool grass
Sparganium fluctuans (Morong.) Robins.	Bur-reed
S. chlorocarpum Rydb.	Bur-reed
Sphagnum spp. Dill	Sphagnum
Broad-leaved marsh	
Calla palustris L.	Water arum
Campanula aparinoides Pursh.	Bellflower
Polygonum natans Eat.	Water smartweed
Potentilla palustris (L.) Scop.	Marsh cinquefoil
Ranunculus pensylvanicus L.f.	Buttercup
R. Gmelini DC.	Yellowwater-crowfoot
Sagittaria latifolia Willd.	Arrow-head
Sium suave Walt.	Water parsnip

Table 4.--*Species assignment to floating-leaved and submergent life-forms*

Life-form and scientific name	Common name
Floating-leaf	
Brasenia Schreberi Gmel.	Water-shield
Nuphar variegatum Engelm.	Spatterdock
Nymphaea tuberosa Paine.	Water lily
Submergents	
Ceratophyllum demersum L.	Coontail
(Moss)	Moss
Myriophyllum spp. L.	Water milfoil
Potamogeton natans L.	Floating-leaf pondweed
Potamogeton spp. L.	Pondweed
Utricularia vulgaris L.	Bladderwort

Table 5.--*Species assignment to upland herbaceous life-form*

Life-form and scientific name	Common name
Upland herbaceous	
Achillea millefolium L.	Sheep yarrow
Amphicarpa bracteata (L.) Fern.	Hog peanut
Anaphalis margaritacea (L.) Benth. & Hook.	Pearly everlasting
Anemone quinquefolia L.	Anemone
Apocyrum androsaemifolium L.	Dogbone
Aralia nuducaulis L.	Wild sarsaparilla
Asarum canadense L.	Wild ginger
Aster macrophyllus L.	Wild aster
A. cordifolius L.	Wild aster
Athyrium Filix-femina (L.) Roth.	Lady-fern
Botrychium spp. Sw.	Adder's-tongue
Circea alpina L.	Enchanter's nightshade
Cirsium arvense (L.) Scop.	Canada thistle
Clintonia borealis (Ait.) Raf.	Clintonia
Coptis trifolia (L.) Salisb.	Goldthread
Cornus canadensis L.	Bunchberry
Dryopteris spp. Adans.	Shield-fern
Fragaria spp. L.	Strawberry
Galium triflorum Michx.	Bedstraw

(Table 5 continued)

(Table 5 continued)

Life-form and scientific name	Common name
Geranium robertianum L.	Herb robert
Hepatica americana (DC.) Ker.	Hepatica
Heracleum lanatum Michs.	Cow parship.
Lactuca canadensis L.	Lettace
Lathyrus spp. L.	Vetchling
Lycopodium obscurum L.	Ground pine
Maianthemum canadense Desf.	Maian-themum
Mitella nuda L.	Bishop's cap
Osmorhiza claytoni (Michx.) Clarke.	Sweet cicely
Osmunda claytoniana L.	Interrupted fern
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper
Petasites sagittatus (Pursh) Gray.	Sweet coltsfoot
Polygonatum biflorum (Walt.) Ell.	Solomon's seal
Potentilla norvegica L.	Cinquefoil
Prunella vulgaris L.	Self-heal
Pteridium aquilinum (L.) Kuhn.	Bracken fern
Pyrola spp. L.	Shinleaf
Sanguinaria canadensis L.	Bloodroot
Senecio spp. L.	Groundsel
Smilacina trifolia (L.) Desf.	False solomon's seal
Streptopus spp. Michx.	Twisted-stalk
Taraxacum officinale Weber.	Dandelion
Thalictrum dioicum L.	Meadow rue
Trientalis borealis Raf.	Star-flower
Trifolium pratense L.	Red clover
Trillium spp. L.	Trillium
Uvularia grandiflora Sm.	Bellwort
U. perfoliata L.	Bellwort
Vicia spp. L.	Vetch
Viola spp. L.	Violet
Waldsteinia fragaroides (Michx.) Tratt.	Barren strawberry

VEGETATION MANAGEMENT IN WATER IMPOUNDMENTS: ALTERNATIVES AND SUPPLEMENTS TO WATER-LEVEL CONTROL

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CONTROL BURNING

Controlled burning to change and improve wetland habitat has been used by game managers throughout Wisconsin for many years. It is one of the cheapest tools available for large scale habitat changes. These changes can be either short or long term, depending on the nature of the fire.

However, burning is not without restrictions. Burns that get out of control can be very damaging and dangerous. Poorly scheduled spring burns are a menace to nesting wildlife. Burns made without consideration for the proximity of highways and inhabited areas can cause irritating smoke problems, and poor visibility may result in dangerous highway conditions.

A plan of operation that considers all aspects of the burn and provides for back-up systems to cover foreseeable emergencies should be made in advance. It is necessary to be aware of the problems and try to resolve them. Most important, burns should not be made without an experienced crew with enough personnel to safely do the job. Clearance for the burning should be obtained in advance from the local fire protection district.

REASONS FOR BURNING

Removal of the Annual "Rough"

Removing the dead canopy of the previous summer's vegetation biomass is one of the objectives of most of the game managers who burn wetlands in Wisconsin. However, in some areas it is stressed more than in others. Some of the large marshes in the southern half of the State have extensive portions of the dense peripheral marsh cover burned off whenever conditions for burning are suitable in the early winter or early spring. A good solid ice cover and a minimum of snow are a necessity to make the burn area accessible and to assure that most of the vegetation will be removed by the fire. Since the entire marsh is never burned in any operation, cover for wildlife always remains. Without periodic controlled burns, the shallow peripheral areas of the marsh become dense tangles of dead and living vegetation which makes travel difficult and restricts wildlife use. A winter burn on these areas creates openings that often receive a considerable amount of waterfowl use in the spring. Burned areas green up first, producing succulent new shoots often heavily favored by geese. On burned areas, many seeds produced during the previous growing season are exposed for waterfowl use. Since large quantities of vegetation are removed by the fire, the natural build-up of the marsh floor is slowed and plant succession is held back.

Reduction of Marsh Floor Levels by Fire

This is done only with a very hot, slow-moving fire under dry surface conditions. Extreme heat from the fire ignites the organic soils and causes them to burn downward into the underlying peat. This results in the burning out of depressions that can improve a dense uninterrupted marsh cover. When water conditions return to normal, these bare holes will fill with water and produce some natural appearing potholes. However, there are problems associated with peat burns that should be carefully considered. Burning peat is extremely difficult to extinguish. It slowly burns deeper and deeper into the ground and unless the area can be reflooded, the fire may continue to burn for days, or even months. Peat fires that occurred during the drought years in the 1930's burned many holes in the floors of our dried out marshes. Some of these fires actually continued to burn for years as the drought continued. Smoke clouds from these fires covered large areas and were a source of more than a little annoyance. Considering the problems we already have with air pollution, long-burning peat fires would hardly be considered acceptable, even if they do improve the wetland habitat. Peat burns, whether intentional or unintentional, seem to be quite attractive to waterfowl.

But burns should only be encouraged if they can be controlled and extinguished within a reasonable period of time.

Control of Woody Vegetation

This is one of the most common objectives for burning in Wisconsin. Without controlled burning, shrubs tend to gradually invade the peripheral sedge-grass meadows and produce a shrub swamp. Fire is the most economical means of retarding this encroachment. To produce an effective burn there must be sufficient understory of grass and herbaceous material to provide fuel for a hot burn and good top kill. Burning should take place in August and September when the woody species are still actively growing. Any vegetation is more susceptible to injury during its period of active growth. In some areas the objective has been to remove woody cover from the lowland meadows and restore the original prairie cover. Summer or hot weather burning is certainly more effective in controlling woody cover than dormant season burning. Late summer or early fall burning, after the active nesting season is past, will cause much less damage to wildlife.

Destruction of Sphagnum to Bring About a Recession to Grasses

Many of the waterfowl impoundments in northern Wisconsin contain areas of sphagnum and leatherleaf bog. Hot fires during the summer and early fall are very effectively used to set these species back and produce conditions suitable for a change to grasses and sedges which are more useful for waterfowl and sharptail grouse management.

Cleaning Impoundment Basins Prior to Flooding

Before flooding an area that contains a large amount of ground litter and woody cover, it is desirable to remove as much of this material as possible through a preflooding burn. A burn will hasten the death of the shrub cover when it is flooded. Stains may leach from woody debris on the impoundment bottom and add more color to the already deeply stained water in acidic northern wetlands. However, all brush need not be eliminated since some woody cover may be desirable. Flooded brush areas sometimes receive good waterfowl use--especially from molting waterfowl which find the brush to be an attractive cover.

Production of 'Greens' for Early Spring Use by Waterfowl

If areas are burned during the dormant period, the annual rough is not only removed, but the area greens up earlier in the spring. There are probably two reasons. First, the overstory of old dead stems is removed and the new plants are released from their shade. Second, the charred and blackened surface absorbs more solar energy and warms the soil for plant growth. Because these areas are free of the usual dense vegetative tangle, they are more attractive for waterfowl use. Seeds from smartweed, burweed and other aquatic and moist soil species are exposed by the burn and are more accessible to waterfowl. This, coupled with the succulent new growth released by the burn, may provide excellent goose grazing. Studies have shown the new growth that follows a burn is more nutritious and more palatable than new shoots produced in an unburned area (Komarek 1965).

Waterfowl Nesting Habitat Improvement

Irregular, patchy burns made on semi-dry sedge grass areas during the dormant season can be used to increase edge effect during the spring nesting season and improve its accessibility to the birds. Cattail cover burned during the winter or fall period when the water is low can become excellent coot nesting in the spring when water covers the stubble. The many isolated small patches of unburned vegetation that remain are ideal as coot nesting sites. This is only true if the area is well flooded in the spring.

Effects of Fire

Studies have shown that fire produces more nutritious and palatable forage than is produced in unburned areas. The many seeds, which are normally present in the rank cover, are made more readily available to waterfowl. In general, flower and fruit production may greatly increase in the perennial cover that was burned off. At the same time, there may be a release of smartweed and millet seedlings which produce more abundantly in the burned area. Cotton grass, which provides desirable goose pasture in some northern areas, has been known to increase and flower heavily following an early spring fire (Linde 1969).

Fire is an ancient management tool. The Indians burned the prairies regularly to make travel easier, flush out game and produce desirable food plants.

Burning Techniques

Fires may be either low intensity or high intensity. Most fires used in marsh management work will be high intensity fires or very hot fires. Hot fires are needed to produce a relatively clean burn that will carry through sparse, coarse vegetation having low flammability.

Conditions that keep fire intensity at a low level are:

1. High humidity and high fuel moisture content.

2. A backfire moving into a strong wind which beats the flames to the ground.
3. A headfire driven by a relatively strong wind that causes the fire to move so fast that an incomplete burn is obtained.
4. Sparse vegetation of low stem density and flammability.
5. Cold air temperatures.

Conditions needed for a high intensity fire are:

1. Low to normal humidities and low fuel moisture content.
2. Warm to hot air temperatures.
3. Fuels with high flammability, and high stem density.
4. A very slow-moving backfire moving into a light wind.
5. A head fire moving with a light to moderate wind.

When to Burn

Avoid all burning in the spring nesting period during April, May and June. Early nesting mallards may be present even in the latter part of March in the southern half of Wisconsin. Late summer or early fall burning are best. However, this may cause some conflicts by removing cover on heavily hunted areas. This can be resolved by patch or strip burning these areas so that a portion of the cover remains for hunting. This could be an asset to the hunters since it improves access for hunters in dense areas.

Winter and early spring burns before the ice is out probably conflict the least with other interest but, at the same time, are less effective. Burning cannot be satisfactorily accomplished if there is a heavy snow cover. It must be done in advance of the snows or after most of the snow cover has melted.

CRUSHING AND MOWING

This management practice is not new, but it is not as widely used as it might be. The reason may be that, unless the treatment is carefully timed and executed, the results can be mediocre to poor. It has been principally used to control cattail (Nelson and Dietz 1966), but other species can also be controlled if treated at the proper time during their growth cycle. This practice has been the basis for some cattail control studies in Wisconsin (Linde *et al.* 1976). The results of these studies more closely defined the treatment period in terms of the normal seasonal changes in food reserves of the cattail and related these changes to phenological events.

Types of Injury Imposed

Destruction of Food Reserves

In the southern half of Wisconsin cattail aerial shoots usually begin growing in May and fruiting plants reach their maximum height in the middle of June when the plant is in full flower. During the early period of leaf growth, the plant is drawing heavily on its carbohydrate reserves stored in the rhizomes. These food reserves were produced and stored during the previous growing season. After the crop of new leaves reach full size, they begin to replace carbohydrates in the rhizomes that were used up in leaf production. By the end of the summer there is once again an adequate supply of carbohydrates available to produce shoots during the next growing season. Just before the new leaves begin to produce carbohydrates in excess of their immediate needs, the plant reserves are low and the plant is then most susceptible to injury. If the new shoots are destroyed by crushing, when the carbohydrate reserves are depleted, additional energy will be required to replace them and the plant may be stunted or killed in the process. The degree of kill depends on how accurately the crushing was timed and how effectively the area was crushed.

Crushing should take place during the summer low point in the plant's reserves. The injury will then be most effective. Treating before or after will leave the plants with a greater amount of food energy and the results will be less satisfactory. For field purposes it would be impractical to determine the percentage of carbohydrates present in the rhizomes. However, we know from our studies that the low in food reserves in the hybrid cattail *Typha glauca* is close to the time when the pistillate spathe leaves are being shed and the pistillate spikes have fully emerged. These phenological check points are suitable for use in the field. Plants properly treated at this time should suffer maximum injury. Since individual plants on any particular area vary in their development, it is important to check a representative number of plants. Plants should be treated when most of them are in the desired growth stage, not by the calendar, because weather varies from year to year.

A rolling drum crusher made from a 55-gallon oil drum or an old hot water tank works very well for crushing (Buele 1979). Angle iron cleats are welded at intervals around its perimeter to help crease and crush the leaves. An axle is fastened to the center of the roller at either end. Except for the cleats, the general construction resembles that of an oversize lawn roller. Since the roller is water tight, it can be filled with sufficient water to give it the desired weight for accomplishing the crushing. A medium-sized, all-terrain vehicle (ATV) which has six or more wheels and is

equipped with tracks can be used to pull the crusher drum. Crushing should continue back and forth over the area being crushed until all the stems are completely flattened. If soil conditions are wet or there is some surface water, the crushing is usually more effective. The tops are then ground down into the mud by the crusher and the ATV tracks. This produces more injury to the shoot base and to the rhizome buds which produce the next generation of shoots. Variability in field conditions produces a variability in the results of the crushing. Excellent results can be attained with a single well-timed crushing if field conditions are favorable. However, successive annual crushings are more likely to produce a satisfactory control. Longevity of the openings produced by crushing is influenced by original size of the openings. Small openings quickly grow in due to invasion of cattail from around the periphery. Openings are best constructed as large as practical and peripheral invasion should be treated annually or biennially if permanent openings are to be maintained. Treatment can be made again the following year, when the reserves are at their low point. Treatments in successive years progressively reduce cattail regrowth to little or nothing.

Eliminating the Oxygen Flow to the Rhizomes

It has been established that the leaves of cattail and other emergent aquatics provide oxygen to the rhizome system through the conductive tubes or arenchyma cells (specialized air conducting cells) in the leaves (Classen 1921). This process is in operation throughout the year, even during the winter months after the leaves are dead. The mechanical structure of the leaf does not change after it dies, but continues to provide passageways for air from the surface to move downward to the rhizomes. As long as the leaves project above the surface of the water and are not crushed or sharply bent, they are conducting to the rhizomes. It is obvious, therefore, that if this important air flow to the rhizome is shut off the rhizomes will eventually die. It has been shown that rhizomes can withstand about 2 weeks or anaerobic conditions in the dormant state (Laing 1941). This characteristic of the plant becomes the basis for a control technique. If the leaves and shoots are mowed in the late fall or, on top of the ice in early winter, and the stubble is flooded and remains covered with several or more inches of water until spring, the plant can be killed satisfactorily. Work can be done with a farm tractor and a rotary cutter (Linde 1969). To submerse the cut stems in deep water areas where there is no possibility of increasing water depths further, mowing will have to be done under water. An underwater weed cutter is required (Buele 1979).

Remember that any stems or leaves, either living or dead, that are not cut will be conducting air and the kill will be less in this area. Since the rhizome network extends out into uncut areas, control will be less effective near the edges of the cut area. Oxygen is conducted through the rhizome network for varying distances. This means that it is harder to achieve a kill in the peripheral areas because they are being supplied with oxygen through rhizomes outside the treated area.

HERBICIDES

Use

The principal use of herbicides on Wisconsin wetlands has been for tree and brush control in the wetland basin and on the dikes. Many thousands of acres of lowland trees and brush were sprayed to clear areas for impoundment development and also for opening up areas for sharptail grouse and prairie chicken managment. Herbicides have also been used for cattail control, but on a large scale.

In recent years the popularity of herbicides has declined. Much of this decline can probably be attributed to a greater awareness of the hazards of chemical sprays, tighter state and federal control on their use, and the outlawing of some of the more popular herbicides such as 2-4-5-T. In addition to state and federal controls, there is a moratorium on the use of herbicides in at least one of our field districts in Wisconsin. Use of herbicides must conform with State and federal regulations.

Spray Equipment for Wetlands

Back-pack Sprayers

These are small sprayers of 3 to 5 gallon capacity, intended only for spraying very small areas. They are suitable for spot spraying or touch-up work.

Power Operated Sprayers

Sprayers of this type may have their own power source or they may be operated from the power take-off of the tractor that carries the sprayer. Although the power take-off models have a lower purchase price, they also have the disadvantage of being difficult to calibrate at low tractor speeds. Reducing the tractor speed also reduces the speed of the sprayer pump which then pumps a lower volume of herbicides at a reduced pressure. Tractor speeds are determined in advance, based on the size of the area to be covered and the quantity of herbicide to be applied. If the spray area is small and application rate is large, the tractor speed may need to be slow. At very low tractor speeds, it may be impossible to have sufficient volume and pressure to obtain proper coverage of the spray area.

If the sprayer has a self-contained power source, tractor speeds have no effect on the output of the sprayer pump. This eliminates an undesirable variable and simplifies spraying.

There are a variety of spray nozzles available for use on power sprayers. In Wisconsin, the "T" or Brodjet nozzle has found considerable use in spraying woody sprouts. This is a single cluster of nozzles that spread a fan-shaped spray pattern from either side of the sprayer head. The gun sprayer is used for brush control work where stem density is too great to allow a fixed nozzle spray to penetrate, or where brush is in patches. Gun sprayers are hand held, making it possible to change the spray angle to better penetrate the stem clump and obtain increased coverage.

The mist blower is a special power sprayer with a self-contained power source nad a very high pressure pump. It throws out a vapor-like spray that provides excellent coverage. However, the light weight spray cloud tends to drift and may affect areas where it is not wanted.

Aerial Spraying

This work requires specialized equipment usually obtained by contract. Since aerial spraying is most efficient when large acreages are treated. Costs may be prohibitive on small areas.

Types of Herbicides

Foliar Herbicides

These are compounds that are absorbed through the leaves. To be effective, they must be applied only to actively growing foliage. Vegetation that has been mowed and burned before spraying to eliminate debris must have time to make a good regrowth before it is treated. Foliar sprays must be used carefully so that the vegetation in the sprayed area is not accidentally burned before the herbicide has produced its full effect. Fire immediately after spraying can negate the herbicide effects since the herbicide will be destroyed before it has a chance to be translocated through the plant. This could result in little or no control. Water soluble foliar sprays should remain on the plant at least 6 hours to insure translocation. A rain before this time could reduce control. The most active stage of growth, during food translocation from leaves to stem is the best time for treatment. This occurs as soon as the leaves are fully open and actively growing. Treatments later in the summer, when the leaves are mature and active growth has ceased, will produce poor results since translocation is at a minimum.

In Wisconsin, the foliar sprays Radapon and Amitrol T have produced good results in cattail control. The principal herbicides used for controlling woody vegetation were 2-4-D and 2-4-5-T. These have now been banned because of a health hazard. Tordon, a combination foliar and root spray is a substitute.

Root Absorbed Herbicide

These chemicals are absorbed from the soil and usually act only through the roots, not through foliage (Tordon is an exception). Removing the foliage and ground debris by mowing and then burning allows the herbicide to be more quickly and completely absorbed, with less waste. Moderate rains following treatment soak the chemical into the soil and speed absorption. Rains heavy enough to produce run-off are not desired.

Heavy doses of root absorbed chemicals may affect plant growth for a year or more. Re-invasion of the area is slow, so application rates of the chemicals should be just high enough to do the job.

Examples of root absorbed herbicides are Simazine, Atrazine and Tordon; the liquid formulation of Tordon is a combination root and foliar herbicide which can be persistent. Simazine and Atrazine have ben used only experimentally on Wisconsin wetlands. They tend to persist more than one season if application rates are high. Studies indicated that smartweeds could be released in grass cover by using either Atrazine or Simazine. Mowing and burning before treatment reduced the amount of Simazine needed by two-thirds (Linde 1969: 111). Atrazine use was also less after burning. Smartweeds, however, are somewhat tolerant of Atrazine.

Tordon is also available in pellet form. The pellets are broadcast and their effects slowly released to plant roots by rain. Pellets are effective in controlling brush on dikes.

WETLAND FARMING

Wetland farming can only be used where water is adequate and where the level can be controlled. Control structures must be properly sized and located to permit water to be rapidly removed in the spring for early seeding. If normal tillage practices are to be used, bottom contours must be such that there are a minimum of pools in the planting area where water fails to drain. It is highly desirable to have supplemental dewatering equipment, such as a high capacity propeller pump or a siphon, to speed up dewatering during wet years. For fall reflooding, a dependable source of water with an adequate flow is a necessity. Sufficient water must be available to flood the crop in time to

attract waterfowl during fall migration. If you reflood by pumping, (as often done in sub-impoundments), make sure the pump is dependable and large enough to raise the water levels at the desired rate.

TILLAGE FARMING

Dewatering

Remove water from the impounded area as early in spring as possible so that the soils have sufficient time to drain and dry properly for tillage with conventional farm equipment. The water table should be 12 or more inches below the surface to permit plowing or rotovating.

Tillage

Mechanical tillage is one of the most expensive techniques used in wetland management. Costs vary depending on soil type, effectiveness of water level control, and vegetative cover. In flat, shallow impoundments, the soils may be slow to drain. Above normal precipitation during the spring and summer may cause wet soils to persist into the summer until it is too late to seed a crop that will mature. If the area has never been farmed previously, you'll need a breaker plow or a rotovator to break up the vegetation mat and produce a suitable seed bed.

A variety of plows and other equipment have been used for ground breaking on wetlands in Wisconsin. Breaker flows varied from 18 to 36 inches. They were pulled by crawler tractors that ranged from D-4's to D-8's. In one instance, two D-2 tractors in tandem were used. Such heavy equipment obviously boosts costs. Breaking costs can be reduced or eliminated if new wetlands can be held at full pool for several years to kill the vegetative cover where food patches will be established. This is usually possible if food patches are to be established in sub-impoundments, providing that muskrat tunnelling does not cause problems in the impoundment dikes during high water. If the areas to be farmed cannot be flooded deeply enough to kill existing vegetation, land breaking will be required.

Rotovating is more economical than plowing if the water table is deep enough that the soil will support a heavy farm tractor and rotovator. The rotovator shreds the sod and eliminates the need for discing. A 71-inch rotovator mounted on a 707 International diesel tractor[1] was used in east central Wisconsin (Linde 1969: 80).

Seeding

With mechanical tillage, a conventional grain drill can be used for seeding. This distributes seed more effectively, provides for better seed germination, and is more economical.

MUDFLAT FARMING

Dewatering

Remove water somewhat later than when you use tillage techniques. Mudflats should be wet so that the seeds will settle into the soil surface and germinate better. Seed by mid-June so the crop matures by waterfowl season. A high water table at seeding time usually precludes using a tractor and grain drill.

Hand Seeding by Tractor

A specially modified crawler tractor, known locally as a "mud puppy", was developed in central Wisconsin to eliminate the necessity of walking and using a hand operated cyclone seeder (Linde 1969). Thirty-inch wooden 2- × 4-inch cleats were bolted on the tracks at intervals, effectively supporting the tractor on wet soils. A man standing on a special platform on the rear of the tractor used a cyclone seeder to seed the mudflats.

Wet Seeding

This is a technique presently being used in northwestern Wisconsin to seed Japanese Millet (Wiita 1982). The millet seeds are soaked in water 24 to 36 hours before planting, causing them to sink. While the planting area is still partially dewatered, the wet millet is broadcast by hand from a boat. The seeds lodge in the mud bottom and the remainder of the water is then drawn off. Very few seeds are pulled out of the planting area by the dewatering process. The technique is simple, fast and effective, but is only suitable for use with Japanese millet or other seeds which can tolerate saturated soils and flooding--and which absorb water and sink.

Aerial Seeding

Aerial seeding is probably the most efficient method for a large area. It is quick and effective and not hampered by wet ground, which is desirable for early germination. The prop blast helps drive the seeds into the bottom soils, improving germination. Commercial crop dusting services often have specialized equipment for aerial seeding. To maximize the effect of the propwash and confine the seeded area, flight altitude should be 35 feet (Linde 1969). Narrow bands can be seeded as drawdown progresses over several days.

A conventional light aircraft can be used for seeding if a commercial crop dusting plane is not available. In

[1] *Mention of trade names does not constitute endorsement by the U.S. Department of Agriculture, Forest Service.*

northeastern Wisconsin a makeshift seeding apparatus was made from a piece of stove pipe and a funnel. The stove pipe was extended from an opening in the plane while an observer poured seed into the pipe through the funnel and the pilot flew 150 feet above ground. Results were satisfactory.

Japanese Millet

Japanese millet (*Echinochloa crusgalli*) is undoubtedly the best food crop planted on wetlands in Wisconsin and produces the most consistent and satisfactory results. It is very tolerant of most wetland conditions, being able to germinate and survive in saturated soils and even in shallow flooded puddles (Linde 1969). It is also tolerant of acid conditions (McLain 1957). Japanese millet will continue to grow under flooded conditions as long as the leaves are above the surface. This allows it to be flooded well before the plant is mature--a positive trait in northern areas where early frosts are common. Flooding to prevent frost damage is, of course, a well-known part of cranberry culture. Because of the residual heat in bodies of water covering flooded areas, frosts must be severe before they will damage millet crops growing under flooded conditions. However, early flooding may cause problems. Waterfowl work back into the flooded areas and walk the plants down to get to the seeds. An early maturing crop that is flooded may be used up well before the waterfowl season begins if the crop is small. If the planting is large, there may be sufficient food available through the season despite its early use. Several plantings made at intervals can provide a continuing supply of food, as long as flooding is also progressive so that all the crop is not exposed to bird use at one time. This method keeps birds out of the late plantings until they are matured and have been flooded. It spreads use of the crop out over a much longer period of time than if the entire area was planted with one seeding and flooded as a single unit.

Deer Damage

Deer graze the young seedlings and may also feed on the mature seed heads. If the planted area is small, the entire crop may be destroyed. Rye fields planted near millet have been successfully used to divert deer from the millet (McLain 1957).

Blackbird Damage

Blackbirds can also be troublesome in millet plantings, but if the planted area is large enough, usually there is sufficient seed produced to feed both the blackbirds and the waterfowl. Blackbirds knock many seeds into the water and these are still available for waterfowl use. In southeastern Wisconsin seeds wasted by feeding birds may be sufficient to produce a sizable second year crop, without additional seeding. In the north, second year crops are rare.

Other Millets

Proso, Browntop, and German millets have all been used as waterfowl food crops in impoundments in Wisconsin with poor results. All of these species are susceptible to water and frost damage and will not tolerate flooding. So they can only be used in places where the usual tillage practices are possible. They cannot be flooded until they mature. There seems to be no advantage in using these species since Japanese millet is far more tolerant and productive under wetland conditions.

Smartweeds

Smartweeds are common invaders of mudflats in Wisconsin. They are tolerant of wet soil, flooding, frosts (often maturing after the first frost), and of great value to waterfowl as food, One of the most prolific and widespread smartweeds is *Polygonum lapathifolium.*

Smartweeds need mudflats by late May or June, on which to germinate and develop. They may be seeded before this time either naturally or by planting. The seed will germinate after the surface soil begins to dry. After frosts have dried the plants, waterfowl begin to use them heavily.

When both Japanese millet and smartweed are present, waterfowl use the millet first and then the smartweeds (Linde 1969). Seeding of smartweed may be warranted in northern Wisconsin, where the season is too short to plant Japanese millet, but seeding is seldom needed in the southern half of the State. Natural seeding of smartweed is adequate in the South.

Buckwheat

Buckwheat (*Fagopyrum sagittatum*) has been one of the more preferred wildlife foods planted in Wisconsin wetlands. A short-maturing variety such as "Duck wheat" has high yields and is less susceptible to frost damage than other varieties. It grows better on poorer soils and sets seed under more adverse conditions than other buckwheat varieties (Stanton 1957).

Good crops of buckwheat are obtained on drained bottomlands if allowed to mature before flooding and frosts. The average date for seeding buckwheat in Wisconsin wetlands is the 26th of June (2 weeks later than Japanese millet) (Linde 1969). Mechanical tillage is usually used and the seeds are drilled in. Seeding in northern Wisconsin should probably be about 3 weeks earlier to avoid early fall or late summer frosts. Buck-

wheat can be hand seeded on mud flats in small wetlands, but it is also well adapted to tillage.

Since the growing season in Wisconsin varies from 30 days in parts of the northeast to 140 days in the southeast, planting dates will need to be adjusted according to local conditions. Generally the northern half of the State is about 3 weeks behind the southern half, but there are many exceptions to this statement. Plant according to local planting rules.

REFLOODING

Timing is important. If flooding begins too early, the food crop may be utilized before the hunting season opens. The area will have lost its attractiveness to waterfowl and will not hold them through the hunting season. If reflooding begins too late, the birds will not have established use patterns before they are disturbed by hunting, so they may not stay.

If the area is large enough, and bottom contours are suitably variable, the crop can be made available to the birds in stages by gradually flooding the planted area. Seeding at intervals in the spring, combined with progressive flooding in the fall, can provide food through the entire waterfowl season if the planting is large enough.

In west central Wisconsin, where several hundred acres of Japanese millet were seeded and another 500 acres of smartweeds were produced, progressive flooding made available from late summer through fall sufficient food to more than supply all waterfowl needs.

MODIFYING SEMI-DRY WETLANDS TO INCREASE WILDLIFE USE

Potholes

Wetlands frequently have relatively large areas of semi-dry sedge-grass meadows around the edges. These areas are a normal part of the wetland and may be important in storing nutrients and filtering out suspended materials when flows are strong. How can we make them more productive for wildlife? In many cases--by building potholes. The sedge-grass cover provides waterfowl nesting habitat, but the important small water areas needed for breeding pairs is lacking. By constructing a series of small potholes in the sedge-grass meadows, we have not destroyed the meadow, but merely added another dimension to it--open water. The meadow can still filter and store nutrients, but now it also provides habitat for breeding waterfowl, and is more useful for other wildlife such as deer, raccoon, mink, and marsh birds.

Wisconsin game managers have used this technique on various methods throughout the State. In many cases, the results have been highly satisfactory. In portions of the State where waterfowl breeding populations are normally high, the potholes were readily used and results were good. However, in places where other bird populations were present, this additional habitat was used to a lesser extent. Apparently bird populations must increase in these areas before this additional habitat will be fully used.

Potholes should be located within the normal traveling range of breeding pairs as they move to and from the larger open-water areas of the marsh. Consider locating potholes near waterfowl brooding areas such as a deep-water marsh, a stream or river, or a large ditch or pond. Brood areas can be constructed, if there are none nearby. Although waterfowl are known to travel with their broods one to two miles or more to suitable brood water (Evans and Black 1956), the closer they are, the fewer the chances of predation.

In Wisconsin, excavated potholes (bulldozed or dragline) are rectangular and most commonly--about 15 to 20 feet wide, 40 to 60 feet long, and about 4 to 5 feet deep. Bottom contours generally include two shallow edges sloping to a deeper center; the opposite two sides are steep. The shallow edges provide the conditions desired for puddle ducks and the two steep edges reduce the encroachment of emergent vegetation into the pothole. Optimum spacing is about 200 feet (Hammond and Lacy 1959). Grouping the potholes in a block pattern is desirable. Excavated potholes get more bird use than blasted potholes, but they are more expensive as well.

Bulldozed Potholes

These can be economical, accurately contoured, and have well shaped spoil banks if bulldozed in dry to moist mineral soils. Most bulldozer work occurs in the northern part of the State where mineral soils are more common.

Dragline Potholes

If the water table is on the surface, the dragline is more practical to use. It can be operated on supporting log mats when the soils become too soft to support its weight. Mats must be moved before the dragline can move to a new location; this necessarily slows up production and increases costs. The dragline can also operate without mats on a frozen surface. Movement between construction points is then faster, but a steel ball must be used to break the ice and frost layer before the excavation can begin.

A dragline cannot level spoil banks as well as a bulldozer. Spoil is usually cast in a loose pile along the edge. Bird use seems as good on a pothole with rough spoil banks as on one where the spoil is leveled.

Moving a dragline and other heavy equipment in and out of an area is costly so there must be enough potholes constructed to make the operation cost effective. If the course along which potholes are to be constructed is "U-" or circle-shaped, it will bring the dragline back to its starting point and increase its efficiency. This will result in it working continuously with breaks only for moving between potholes.

Blasted Potholes

Potholes have been blasted in both large and small marshes in Wisconsin. ANFO (Ammonium nitrate fuel oil mixture) was introduced in the early 1960's (Mathiak 1965), and has replaced dynamite. It costs only 1/10 as much as dynamite and it is considerably safer to handle. A 50-pound bag of ammonium nitrate fertilizer treated with fuel oil is detonated with a stick of dynamite and a standard blasting fuse or electric detonator. This charge will create a hole 19 to 35 feet in diameter and 30 to 72 inches or more deep, depending on the soil and water conditions (Mathiak 1965). Bottom contours vary from cone- to bowl-shaped. Even within the same area, pothole sizes may vary considerably. However, the cost per pothole is much lower than for any other type of construction.

The bottom of blasted potholes is usually cone-shaped and the edges are very steep. Sloughing continues for up to 2 years before the bottom stabilizes. These are not disadvantages if the potholes are considered only as breeding pair sites in the spring when water levels are high. Even if a perpendicular edge is exposed by evaportranspiration in the middle of the summer, the pothole has already served its purpose for that year as a breeding pair site. More than one pair of waterfowl at a time have frequently been observed on blasted potholes in southern Wisconsin. In a normal year the potholes remain full of water until early summer when breeding pair activity is mostly over.

Blasted potholes are so cheap that new ones can be blasted as soon as their short life is over, even on a limited budget. Although small, blasted potholes are well within the size needed by puddle ducks (Evans *et al.* 1952).

Runoff Ponds

Runoff ponds can provide brooding areas on the periphery of wetlands. To construct one, place a short dike across an upland drainageway emptying into a marsh. This creates a small impoundment of 1 to 5 acres or more, depending on the edge and drainage contours. If soils are clayey, remove soil from the pond bottom adjacent to the dike. Using a bulldozer, shape and contour the entire deep end of the pond with gradual slopes to provide deep water for diving ducks. Ponds usually contain 6 to 10 feet of water at the deep end. Deep water encourages use by diving ducks; many marshes are too shallow for them.

About 20 acres of cropland or pasture drainage may be needed for each acre of pond (Addy and MacNamara 1948). The drainage area for the pond must be adequate to keep it well filled through the driest part of the summer. Enlist SCS help when planning a pond of this type.

A fixed level spillway is adequate, but it is probably good economy to provide at least a drain tube through the dike so that the pond can be drained for repairs, vegetation control or maintenance. Birds use these ponds more and more after emergent vegetation begins to invade the shallow edges and provides cover. Birds also find safety in the center of the larger ponds.

A CASE HISTORY

In a red clay area in northwest Wisconsin, seepage is minimal so potholes hold water all summer. The game manager constructed one large 2.6-acre pond and 7 small potholes. Dikes were needed only on one large pothole and on the 2.6-acre pond. The remaining potholes were merely deepenings in the drainage area. All were located in a 40-acre grassy field.

Waterfowl response was immediate. In the spring, the potholes were used by breeding pairs and the 2.6-acre pond became a brooding area. During fall migration, geese as well as ducks were attracted to the potholes. Birds flew between these water areas and a nearby privately owned pond.

During the first year, cattail invaded the periphery of the potholes and the pond to provide desirable edge cover. After several years, the cattail spread out into the center of the shallow potholes. In most instances the cover was thin and probably did not interfere too much with bird use. If the potholes had been deeper, cattail would have been restricted to the edges. The edge cover of the large pond appeared to be ideal for broods. Submergent vegetation invaded the large pond, but never became objectionably dense or rank. More potholes of this type may be constructed within a square mile.

Scattered parcels of land unsuited to forestry (but having the right soils and drainage contours) can be

used for constructing potholes and ponds in upland areas. The value of such a complex increases the closer it is to a large wetland.

LEVEL DITCHING

Muskrat Management

These provide open water for wildlife in shallow semi-dry areas. Level ditches are closed at either end so that they do not drain the wetland. Ditches have been widely used to provide year round habitat for muskrats in semi-dry marsh areas (Mathiak and Linde 1956). Spoil banks serve as den sites for the muskrats. If the ditch is connected with deeper areas, where there is a good supply of cattail or other foods plants, the ditch can be very productive. Water depth should be 4 to 6 feet to provide adequate water through winter. Ditches constructed for muskrat management have been 13 feet wide at the surface, 5 feet deep and 5 feet wide at the base (Mathiak and Linde 1956). Zig-zag ditches are recommended and spoil banks should alternate on either side of the ditch. A zig-zag pattern appears to provide more cover for waterfowl. Alternating spoil banks break up predator lanes to some degree, but are probably not truly deterrent in this respect in semi-dry areas. Space ditches about 200 feet apart.

Firebreaks

Level ditching can be used as a firebreak if it parallels the upland edge of the area to be protected. If the spoil is peat, place spoil banks on the outside of the ditch away from the burn to prevent the banks from burning during a hot fire. These firebreaks are still useful for waterfowl and muskrats and other wildlife.

Waterfowl Brooding Areas

Level ditches may be used to lead waterfowl broods away from the grass nesting areas to safer habitat in the deeper parts of the marsh. If level ditching is constructed specifically to serve as a brooding area, the ditch should be at least 30 feet wide at the surface and zig-zag to provide more edge (Mendall 1958).

REFERENCES

Addy, C. E.; MacNamara, L. G. Waterfowl management on small areas. Washington, DC: Wildlife Management Institute; 1948. 80 p.

Buele, John D. Control and management of cattails in southeastern Wisconsin wetlands. Tech. Bull. 112. Madison, WI: Wisconsin Department of Natural Resources; 1979. 39 p.

Classen, P. W. Typha insects: their ecological relationships. Cornell University Agricultural Experiment Station Memorandum, 47: 459-531; 1921.

Evans, Charles D.; Hawkins, Arthur; Marshall, William. Movements of waterfowl broods in Manitoba. Spec. Sci. Rep. Wildl. 16. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service; 1952. 47 p.

Evans, C. D.; Black, K. E. Duck production studies on the prairie potholes of South Dakota. Spec. Sci. Rep. Wildl. 32. Washington, DC: U.S. Department of Interior, Fish and Wildlife Service; 1956. 59 p.

Hammond, M. C.; Lacy, C. H. Artificial potholes and ditches as waterfowl habitat. Minneapolis, MN: 21st Midwest Wildlife Conference; 1959. 11 p. (mimeo)

Komarek, E. V., Sr. Fire ecology-grasslands and man. In: Proceedings, 4th Annual Tall Timbers Fire Ecology Conference; 1965: 169-220.

Laing, H. E. Effect of concentration of oxygen and pressure of water upon growth of rhizomes of semisubmerged water plants. Bot. Gaz. 102: 712-724; 1941.

Linde, Arlyn F. Techniques for wetland management. Res. Rep. 45. Madison, WI: Wisconsin Department of Natural Resources; 1969. 156 p.

Linde, Arlyn F.; Janisch, Thomas; Smith, Dale. Cattail--the significance of its growth, phenology and carbohydrate storage to its control and management. Tech. Bull. 94. Madison, WI: Wisconsin Department of Natural Resources; 1976. 27 p.

Mathiak, H. A. Pothole blasting for wildlife. Publ. 352. Madison, WI: Wisconsin Conservation Department; 1965. 31 p.

Mathiak, H. A.; Linde, A. F. Studies on level ditching for marsh management. Tech. Tech. Bull. 12. Madison, WI: Wisconsin Conservation Department; 1956. 48 p.

McLain, P. D. Production of waterfowl foods on impoundments and marshes with low quality soils. Paper presented at Northeast Wildlife Conference, New Haven, CT: Division of Fish and Game, New Jersey Department of Conservation and Ecology; 1957. 12 p. (mimeo).

Mendall, H. L. The ring-necked duck in the northeast. Univ. Maine Bull. 60 (16). 1958. 317 p.

Nelson, N. F.; Dietz, R. H. Cattail control methods in Utah. Publ. 66-2. Department of Fish and Game; 1966. 33 p.

Stanton, F. W. Planting food for waterfowl. Misc. Wildl. Publ. 1. Portland, OR: Oregon State Game Commission; 1957.

Wiita, C. B. Personal communication. 1982.

WATER QUALITY AND NUTRIENT DYNAMICS IN SHALLOW WATER IMPOUNDMENTS

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The quality of water in shallow water impoundments is principally a function of water source. The three categories of water sources are: surface water only, about equal mixes of surface and groundwater, and mostly groundwater. These categories are typical of the northern Lake States (and presumably adjacent Canada). Other regions near ocean coasts, in semi-arid areas, and in areas with different rock types will have different proportions of dissolved material in their water, but the water sources are the same and the basic principles of water quality in shallow impoundments discussed below will hold in these regions, too.

The purpose of the present paper is to: 1) show how water quality is a function of natural circumstances; 2) compare 5-year, year-around measurements of water quality on seven impoundments, four free-flowing streams, and a natural marsh on the Chippewa National Forest in north central Minnesota (two or three impoundments in each of three water source categories were studied and matched with one or two free-flowing streams in each category); 3) evaluate water quality in terms of State standards for recreation or fisheries; and 4) examine the impact of impoundment aging and drawdowns on water quality.

WATER TEMPERATURE

The annual water temperature range for four control sites (1975-1978) is illustrated in figure 1. From mid-November through March, water temperatures (measured through the ice) were either 0 or 1° C (winter is defined by water temperatures of 0 to 3° C; summer is defined by water temperatures 4° C and higher). Water temperatures from early April through early November paralleled and varied about the mean monthly air temperature as depicted by the dots in figure 1. Air and water temperatures usually reach an annual high in July about 3 to 4 weeks after solar radiation peaks on June 22. Ice-out can occur anytime in April, and ice-up can occur from late October to mid-November.

Water can warm quickly in May and come close to annual highs in response to warm air masses from the southwest and Gulf of Mexico. Water can cool nearly as quickly in June in response to Arctic air masses from Canada. While the range of temperatures in figure 1 represents four different control (natural) sites lumped together, it is not unusual for a single site (natural or impounded) to have a 10 to 15° range in temperatures over the years for a given month. Water temperature variability is greatest on the warming side of the year and least during cooling in August, September, and October. The maximum side of the temperature range curve has a conspicuous bump in late October and early November. This is God's gift to the frozen fingers of late season duck hunters. Otherwise we call this the "bluebird days" of Indian summer that result from the last brave advances of warm Gulf Coast air in autumn (fig. 1). In some years, it doesn't occur.

There are differences in the range of water temperatures among natural sites that should be understood before impoundment water temperatures are compared to them. The four natural sites are Turtle Mound Creek, draining a large sand plain with few

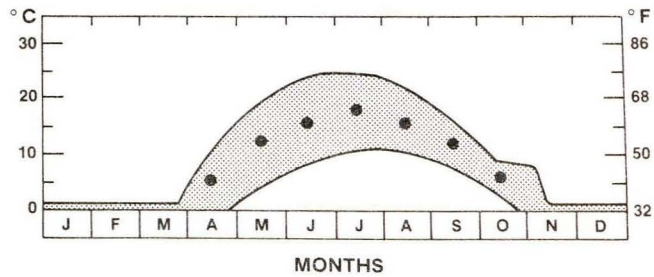

Figure 1.--*The water temperature range (shading) of four natural control sites during a 4-year period (1975-1978) parallels mean monthly air temperature (dots).*

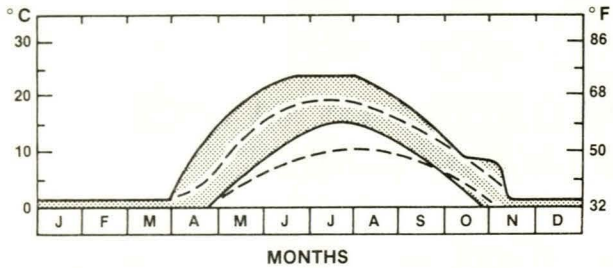

Figure 2.--*The water temperature ranges among controls are separated into those with open water in the drainage (shaded) and a stream without open water areas in the drainage (dashed lines).*

wetlands; Sucker Creek, draining a large area of uplands, wetlands, and a chain of lakes (which are more than a mile across); East Lake Creek which drains a small active beaver area with groundwater springs; and Goose Lake (½ mile long, and classified as a deep freshwater marsh) which receives primarily surface water from a small watershed and has limited outflow.

Water temperatures in Turtle Mound Creek (with no significant surface water areas in the drainage) are consistently cooler by about 5° C than water temperatures at the other sites that have large, open water areas in the drainage. The water temperature in a lake, stream, beaver flowage, and natural deep marsh are similar, but warmer than streams without open water areas in the drainage (fig. 2). Open water areas whether fed by near-surface or deep groundwater sources have similar temperatures that are 5° C warmer than groundwater fed, perennial streams. They also warm slightly faster in April and cool slightly faster in September than streams (fig. 2).

When all impoundment water temperatures are compared to all natural sites with open water, we find that minimum temperatures are identical, but maximum temperatures can rise another 5° C (to 33° C) in July. This additional increase in water-impoundment temperature is not typical, and only occurs in stagnant, diminished pools with no water flow (fig. 3).

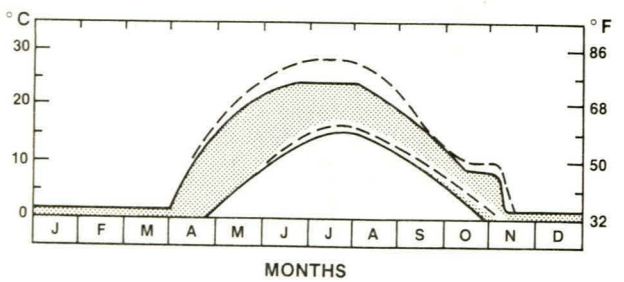

Figure 3.--*The range of impoundment water temperature (dashed lines) is similar to natural open water areas (shaded) for minimum values, but can rise an additional 5° C in stagnant, diminished-pools with no water flow (upper dashed line).*

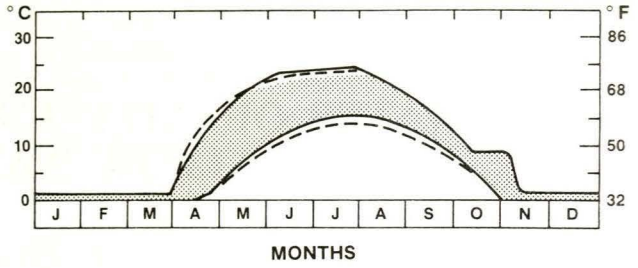

Figure 4.--*The range of water temperature in Ketchum Impoundment (dashed lines) is similar to the nearby Sucker Creek (and lake) (shaded) for groundwater fed areas.*

Ketchum impoundment drains through a quarter mile of stream into Sucker Lake which drains to Sucker Creek where the temperature is measured 100 yards downstream of the lake. All these areas are strongly fed by groundwater, so the ranges in water temperature from Sucker Creek and Ketchum Impoundment are identical (fig. 4). The same is true of Goose Lake (natural deep marsh site) and Cuba Impoundment which are fed by surface water sources and are separated by 35 miles, but this is only true when there is water flowing from the impoundment (fig. 5). The high temperatures depicted in figure 3 occur in diminished impoundment pools (stagnant) caused by purposeful drawdown or dry weather drawdowns in surface water fed impoundments. Table 1 summarizes July water temperature ranges occurring on the Chippewa National Forest.

Impoundment water temperatures exceed 21° C (70° F), which is the maximum temperature for normal trout growth, but maximum temperatures in impoundments with flowing water do not exceed 28° C (82° F), which is below the maximum growth temperatures for northern pike, yellow perch, walleye, small-mouth bass, and sauger (29° C or 84° F), large-mouth bass, bluegill, and crappie (32° C or 90° F), or catfish, white bass, spotted bass, buffalo, carp, and shad (34° C or 93° F).

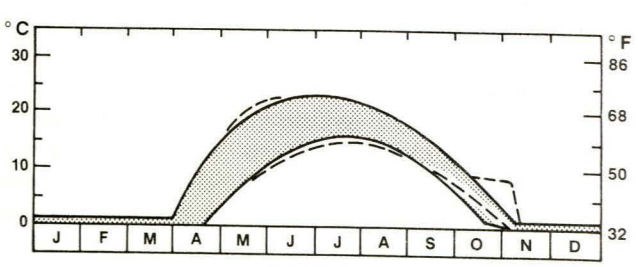

Figure 5.--*The range of water temperature in Cuba Impoundment (dashed lines) is similar to the Goose Lake natural deep marsh some 35 miles to the northeast. Both areas are surface-water fed, but the similarity only holds when there is some water flow.*

Table 1.--*July water temperature ranges on the Chippewa National Forest*

	July water temperature (° C)		
	Maximum	Mid-range	Minumum
Nonflowing, diminished pool impoundments	33	27	22
Flowing lakes, natural marshes and impoundments	28	23	19
Natural streams with little or no open water	23	17	12

Hot water in June, July, and early August can retard fish growth. During these months, the high edge of the water temperature range shown in figure 1 is 8° C warmer than the mean monthly air temperature. Thus an estimate of maximum water temperature in open, flowing water can be made for other locations by adding 8° C to the mean monthly air temperatures in June, July, and August, and an additional 5° C can be added if shallow water impoundments stagnate.

Do impoundments warm their downstream waters too? Very slightly. On a hot day in July with an air temperature of 27.5° C (81° F) we measured a water temperature of 24.5° C (76° F) at the surface of the water impoundment. Within 20 meters (60 feet) of the impoundment outlet, stream temperatures dropped 4° to 20.5 (69° F) and remained at that temperature farther downstream. This drop in temperature occurs because of streamside shading and cooler groundwater entering the stream. The 4° C drop is nearly the same as the 5° C difference between streams (with little or no open water areas in their course) and lakes or impoundments.

DISSOLVED OXYGEN

Shallow impoundments will alter the dynamics of dissolved oxygen from that of unimpounded streams or lakes. Curves delimiting the occurrence of dissolved oxygen in impoundments are depicted in figure 6 for daytime measurements. The upper band from April through November is typical of values found in lakes throughout the year. Shallow impoundments deviate from this pattern in two significant ways.

First, shallow impoundments lose much of their oxygen under ice. When this happens over the long winter (approximately 5 months) a concurrent low redox potential causes a massive migration of nutrients out of the bottom muds and into the overlying waters. In shallow impoundments the layer of enriched waters is no more than 3 to 6 feet--the entire depth of the impoundment. In lakes the cold, mixed waters stay near oxygen saturation over the winter. Data presented by Tonn and Magnuson (1982) confirm low overwinter oxygen levels in northern Wisconsin lakes whose mean depth is 6 feet or less, while deeper lakes exhibit oxygen concentrations over 8 mg/l in January through March.

Secondly, shallow impoundments must handle organic matter surges differently than lakes do. Lakes can pass organic matter into the cool, dark hypolimnion layer. Shallow impoundments do not develop strong thermal stratification as lakes do, thus decay takes place throughout the shallow water. When organic matter is introduced from algae dieoffs, during reflooding over dried organic matter, during concentrations caused by drawdown, and during duckweed die-backs or after leaf-fall, dissolved oxygen concentrations can fluctuate rapidly (principally from June through September). During these conditions, dissolved oxygen will fluctuate from the high range of 5 to 9 mg/l down to the range of 0.5 to 4.4 mg/l (fig. 6).

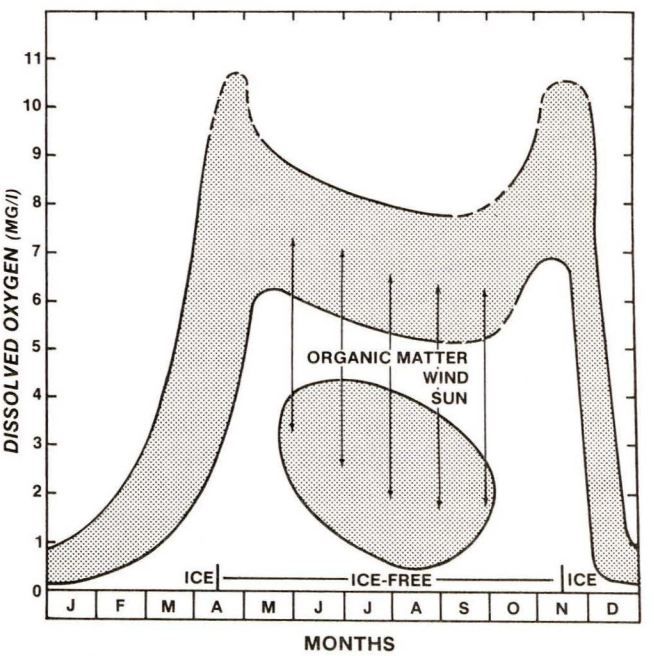

Figure 6.--*Dissolved oxygen in shallow water impoundments (daytime, near surface measurements). During the summer concentrations move between the upper and lower shaded areas rapidly as organic matter is processed and wind mixing or photosynthesis occurs. Dashed lines depict areas of limited data.*

The reduction is caused by the biological oxygen demand of decomposer organisms, but dissolved oxygen concentrations can rebound to higher levels with wind mixing, photosynthesis, and cooler temperatures. Up-down cycles of dissolved oxygen may run for a day or week depending on wind conditions and the amount of dead organic matter. Overnite fluctuations when photosynthesis is reduced can result in similar fluctuations (Lathwell *et al.* 1969).

Shallow impoundments are not well suited for fish populations during the summer or over winter because of these wide fluctuations in dissolved oxygen. The lower dissolved oxygen limits for Class A fisheries and Class B or C fisheries in Minnesota are 7 and 5 mg/l respectively. The spring period (mid-April through May) is not limiting to spawning fish since dissolved oxygen levels average above 5 mg/l, however experimental evidence indicates no loss in maximum swimming speed for northern pike down to levels of 3 mg/l (Adelman and Smith 1970).

TOTAL AND FECAL COLIFORM

Total coliform bacteria populations fluctuate with water temperature; levels are high in summer and low in winter. However, peak total coliform populations tend to lag 3 to 6 weeks behind peak water temperatures (fig. 7). During the ice-free season there is no difference among impounded waters, natural deep marshes, and unimpounded streams; total coliform populations average 900 colonies/100 mls for normal flow conditions. Under no-flow (stagnant water conditions), impoundments and controls both average 5,800 colonies/100 mls. At any single location several samples during the no-flow period exceeded counts of 65,000 colonies/100 ml, our upper limit for actual colony counts. During ice cover, total coliform bacteria persisted at low levels with resting stages capable of multiplying under warm laboratory incubation conditions. Impounded waters averaged 300 colonies/100 ml while all control waters averaged 150 colonies/100 ml. These differences are significantly different at the 10 percent level of confidence but not at the 5 percent level. The differences appear real because the total coliform populations in impounded waters tend to run higher month by month than the controls do (fig. 7). However, throughout the year, total coliform populations measured in all conditions should be considered normal. There are no standards for total coliform except for finished drinking water obtained from deep wells or treated surface waters. Drinking water standards are 1 TC/100 ml.

The numbers of fecal coliform bacteria (colonies/100 ml) run 1000 times lower than total coliforms, but

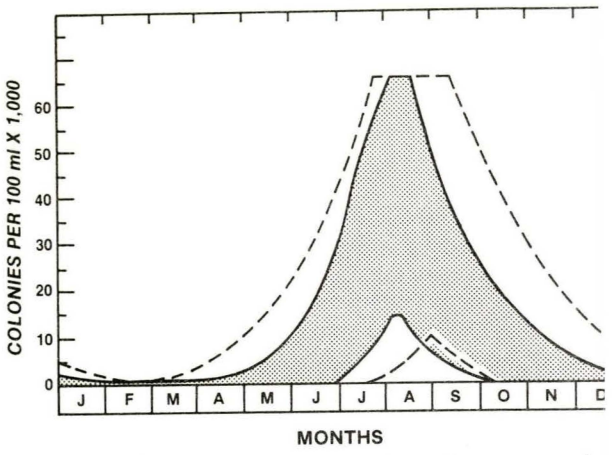

Figure 7.--*Envelope curves showing the seasonal currence of total coliform bacteria in nonimpound controls (shaded) and shallow water impoundme (dashed lines). Truncated tops reflect our too-r merous-to-count limit of 65,000. Three or four valu exceeded this at any one location.*

are a direct measure of bacteria from the intestines warm blooded animals. Fecal coliform bacteria do n follow the slow warming pattern of air temperature total coliform do. Instead, fecal coliform populatio have the ability to explode after ice-out and pers with wide variation until freeze-up (fig. 8).

State standards commonly allow a logarithm monthly average of no more than 200 colonies/100 and no more than 10 percent of individual samples

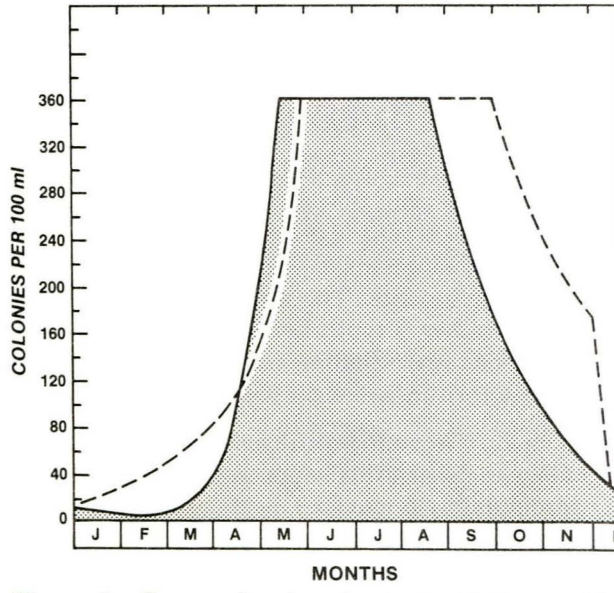

Figure 8.--*Curves showing the seasonal range of fe coliform bacteria in nonimpounded controls (shad and in a range of shallow water impoundme (dashed lines). Truncated tops reflect our too- merous-to-count limit of 360. Three or four val exceed this at any one location.*

exceed 400 colonies/100 ml for all classes of State waters. There are no significant differences between impoundment and control waters. Fecal coliform populations average 3 colonies (per 100 ml) during winter conditions, 8 colonies during summer-normal flow conditions, and 68 colonies during summer-stagnant conditions. Twelve samples out of 529 or 2 percent were greater than 400 colonies per 100 ml. Seven of these occurred on control areas and five on impoundment areas during extremely dry conditions. These fecal coliform levels occur with waterfowl populations at seven per acre or less; over-use by waterfowl can dramatically increase fecal coliform and disease organism levels (Hussong *et al.* 1979).

OTHER WATER QUALITY PARAMETERS

Temperature, dissolved oxygen, and coliform bacteria are strongly related to time of the year, but are not strongly related to water source. Other water quality measures are. High specific conductance, alkalinity, dissolved solids, and calcium plus magnesium, indicate groundwater entering an impoundment area. As values of these measures increase, the more groundwater volume there is, and the deeper and longer groundwater has traveled to reach and surface at the impoundment site (see fig. 2, Verry 1984). These measures of water quality are highly inter-correlated in the Northern Lake State Region; any one can be predicted from another.

Color, nitrogen, phosphorus, potassium, iron, and manganese are primarily associated with organic material and tend to cycle over and over through the root uptake, living tissue, plant decay, and leaching pathways. Though relationships are weak, high values tend to indicate surface water flowing through the organic and A horizons of surrounding mineral soils or through organic soils in wetlands.

Water pH values can fluctuate widely (1-2 units) and will not on any given day indicate the degree of mixing between surface and groundwater sources. Many measurements tend to show a slight positive correlation between pH and large groundwater input, but pH should not be considered a diagnostic tool for evaluating water source.

Impounding water in shallow wildlife production areas will cause only minor changes in summertime water quality if water levels and flow are near normal conditions. Normal flow occurs when water levels are 75 cm (30 inches) above or below the normal pool elevation. Stagnant water (levels more than 75 cm below normal pool) can increase color and nitrogen, but they do not travel out of the impoundment or pose a threat to downstream water quality.

In winter, nutrients increase greatly in shallow impoundments (unlike in most lakes). Even though the increased concentrations are large (2 to 9 times summer levels), they remain within eutrophication standards, but exceed (during most of the year) convenience standards. Because outflow is limited in the winter, impoundments do not pose a threat to downstream water quality.

Mean concentrations will be shown for each water quality measure according to two classifications. One classification is based on season of the year for impoundments: W for winter, SN for summer-normal flow and SS for summer-stagnant. In many cases there is no difference between SN and SS and thus the summer period is shown only as S. Control locations (C) consisting of unimpounded streams or deep marshes (over 3 meters or 10 feet deep) did not show seasonal differences. Winter is any sample taken when the water temperatures are 0 to 3° C; summer when the water is above 3° C. In the second classification, specific conductance was used to group information into three water source categories. They are identified by the mean specific conductance value during summer-normal flow conditions. They are: 70 micromhos (surface water dominated impoundment), 140 micromhos (about equal volumes of surface and groundwater), and 287 micromhos (groundwater dominated impoundments). Standards applicable to fisheries, drinking water, livestock, or convenience are discussed where appropriate.

pH

Impoundment pH values are not different from control values ($\alpha = 0.05$) nor are seasons different. Summer values tend to increase slightly from low to high specific conductance groups (70:6.1, 140:6.3, 287:6.5). Both surface water only impoundments (70) and equal mixture impoundments (140) are below recommended pH levels for all types of fish; thus they are not suited for year-round fisheries (fig. 9). Spring-time spawning areas operated on a net-grow-and-flush basis are an exception to this. Groundwater dominated impoundments have pH levels acceptable to all fish species. For these areas consider the impact of unpassable dams on natural spawning runs.

Specific Conductance

Specific conductance (corrected to 25° C) is easily measured with a meter in the field or laboratory and indicates the amount of groundwater inflow. Because

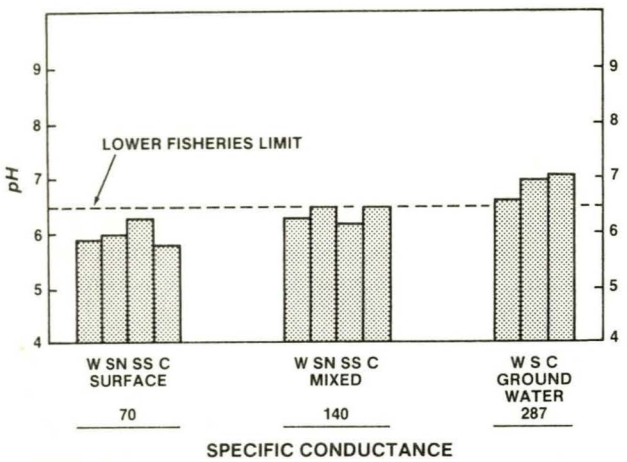

Figure 9.--*pH means in impoundments during winter (W), summer-normal flow (SN), and summer-stagnant (SS) conditions; and nonimpounded control areas in all seasons (C). The three groups of data represent impoundments with different water sources. These are indexed on specific conductance values at summer-normal conditions: surface water only (70), an equal mixture of surface and groundwater (140), and groundwater dominated (287). Bars shaded the same are statistically equal at the 95 percent level of confidence within conductance groups.*

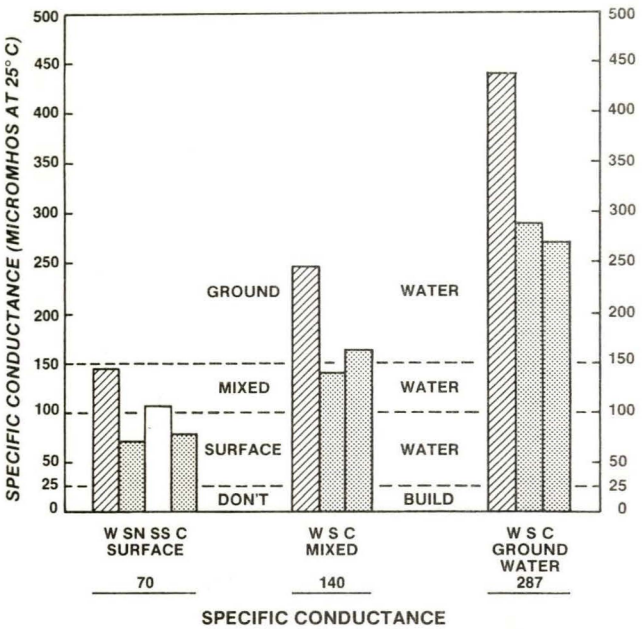

Figure 10.--*Specific conductance means in impoundments during winter (W), summer-normal flow (SN), and summer-stagnant (SS) conditions; and nonimpounded controls (C). Water source labels refer to site selection criteria (Verry 1984). See figure 9 for an explanation of data groups and bar markings.*

of this, it has been selected as a base for comparing water quality in impoundments and for selecting impoundment sites. Figure 10 shows the summer means for specific conductance used to group data on the breaking points used to describe an impoundment's water source. Note the large increases in winter values in all three groups. A similar pattern exists for the other water quality characteristics that are positively associated with groundwater. Correlations of specific conductance with total dissolved solids, total alkalinity, and calcium + magnesium and their corresponding break-points for water source are shown graphically in figures 11, 12, and 13. Note the very low levels of calcium + magnesium and total alkalinity at the do-not-build limit of 25 micromhos. Any of these characteristics can be used interchangeably in the northern Lake States. Regressions of these characteristics against specific conductance may not hold in other areas. For instance, the relationship with Ca + Mg may have a lower slope if another cation such as Na or K is a relatively large part of the cation load.

Because specific conductance is the basis for site selection and vegetation management, one should be aware of the number of samples needed to accurately estimate specific conductance--especially in the 0 to 150 range. Table 2 lists the number of samples needed to estimate within three confidence limits and two confidence levels. Two or three samples will suffice in most instances. With experience and recognition of seasonal flow levels, one will do.

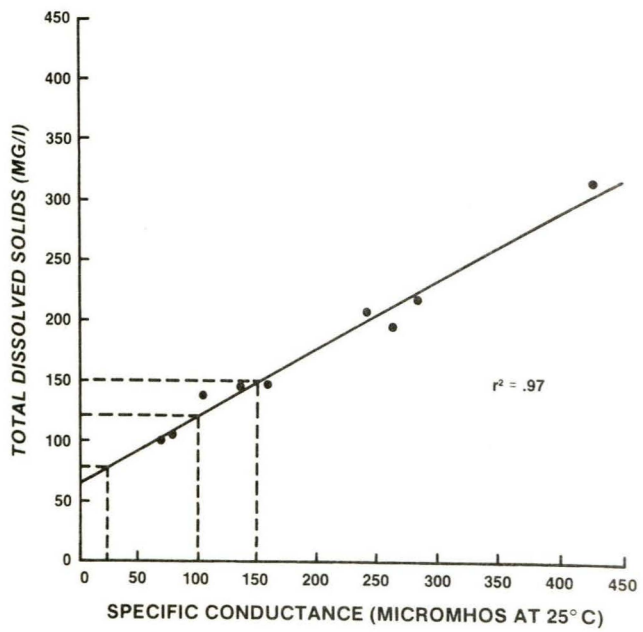

Figure 11.--*The correlation of total dissolved solids and specific conductance; dashed lines refer to site selection criteria based on water source.*

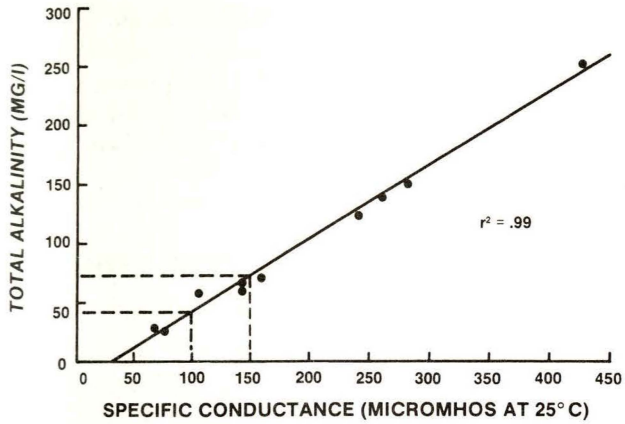

Figure 12.--*The correlation of total alkalinity and specific conductance; dashed lines refer to site selection criteria based on water source.*

Organic Matter

Water constituents derived mostly from organic matter have their concentration levels defined in figures 14 and 15. Again, concentrations are highest in the winter. In most instances, control and summer values are the same. Exceptions occur in apparent color under low flow conditions where the contributing watershed contains organic soils along the side of the inflowing stream. Total nitrogen can also increase in surface water impoundments during stagnant conditions.

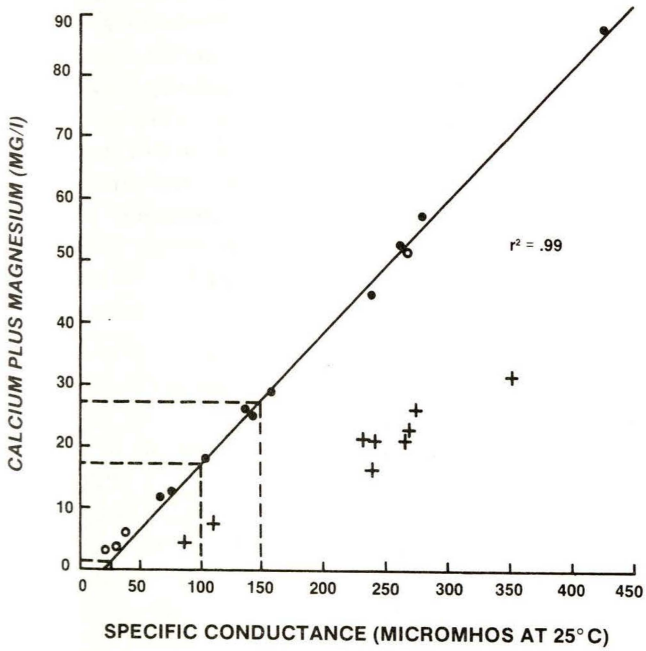

Figure 13.--*The correlation of calcium plus magnesium and specific conductance. Dashed lines refer to site selection criteria based on water source. Solid dots are regression data developed in north central Minnesota. Open circles confirm the relationship at Neceedah, Wisconsin (Baldassare 1978) and Backus Lake, Michigan (Kadlec 1962). X's are data from Reid (1982) for Missouri indicating that another cation (probably sodium) is as important as calcium plus magnesium in that region.*

Table 2.--*Number of samples needed to adequately sample specific conductance during normal flow conditions in summer*

Confidence limits	Confidence levels	
	95 percent	90 percent
± 10 micromhos	8	6
± 15 micromhos	4	2
± 20 micromhos	2	1

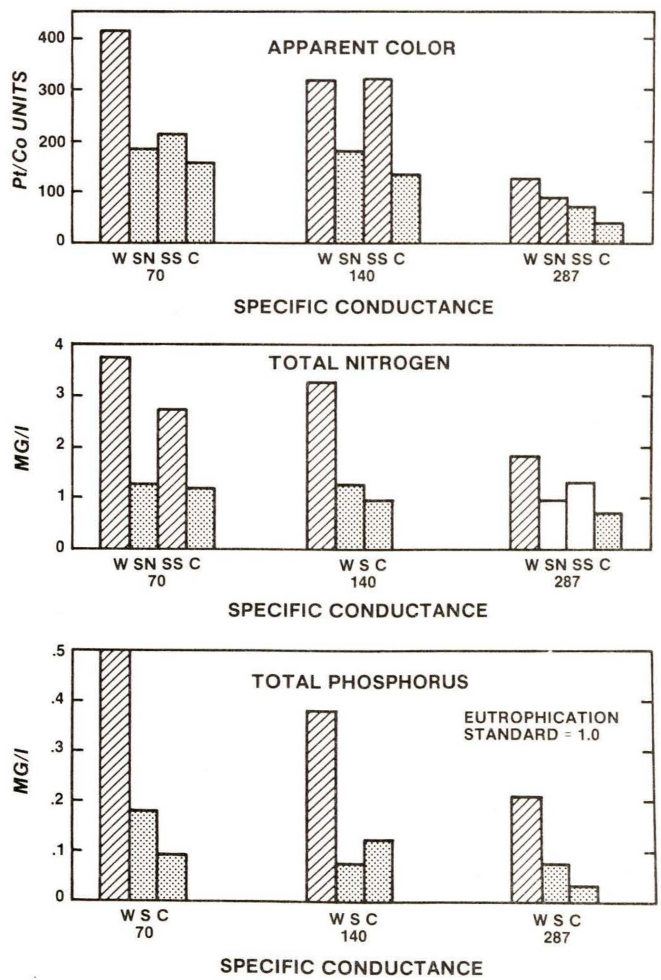

Figure 14.--*The occurrence of apparent color, total nitrogen and total phosphorus means in impoundments during winter (W), summer-normal flow (SN), and summer-stagnant (SS) conditions; and nonimpounded controls (C). See figure 9 for an explanation of data groups and bar markings.*

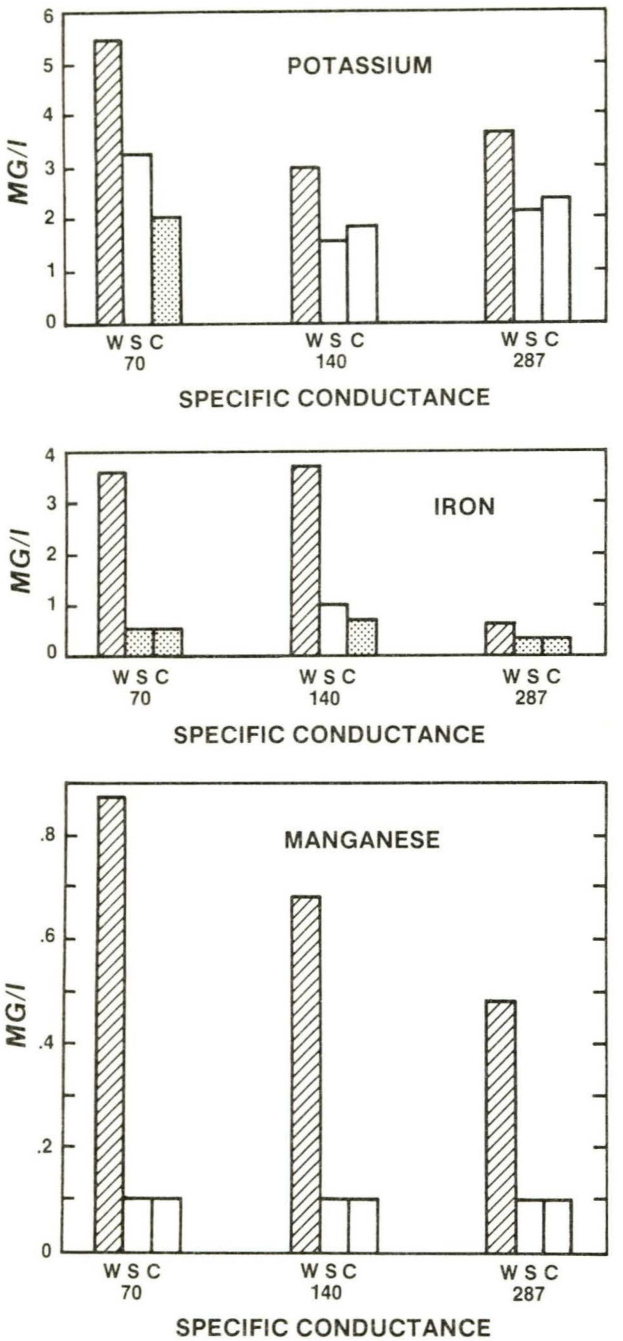

Figure 15.--*The occurrence of potassium, iron and manganese means in impoundments during winter (W), and summer (S) conditions; and nonimpounded controls (C). See figure 9 for an explanation of data groups and bar markings.*

Potassium is easily leached from plant tissue and thus is high in the surface water (70) impoundments, but in strong groundwater-fed (287) areas it can also originate from aquifer rocks. Color, iron, and manganese standards for domestic use are 15, 0.3, and 0.05 mg/l respectively, and are always exceeded, but these standards relate to the taste of coffee made from this water and the brightness of clothes washed in it. The eutrophication standard for total phosphorus is 1 mg/l which is set for receiving lake waters below sewage treatment plants. Impoundment concentrations remain below this standard.

DRAWDOWNS AND WATER QUALITY

Hartman (1949) and McNamara (1957) observed that waterfowl use peaked soon after flooding new impoundments and then slowly decreased. Kadlec (1962) concluded that: "clearly these older unproductive impoundments need rejuvenating." Having observed changes in waterfowl use, several authors sought to show that the underlying causes were at the impoundment site (dismissing any coincidental fluctuations in continental waterfowl populations). Hartman (1949) believed the basic cause was the exhaustion or unavailability of soil nutrients. Cook and Powers (1958) found that soil nutrients accumulated after flooding, but thought that iron or manganese in soil solutions might reach concentrations toxic to plants with time. Kadlec (1962) concluded that: "soil and water analyses indicate a definite increase in plant nutrients" during and soon after reflooding in a Michigan impoundment. Whitman (1976) in summarizing Kadlec's work wrote, "He attributed the high levels of dissolved nutrients, which occurred shortly after flooding, to a rapid release of soluble nutrients from the substrate and the pre-flood terrestrial vegetation. Subsequent declines resulted as the nutrients were reduced by developing flora and fauna or became trapped by the colloidal content of the substrate."

In Whitman's own analysis of impoundments near the New Brunswick-Nova Scotia border, he showed that impoundment fertility (water chemistry) decreased with age. From an age of 6 months to 7 years alkalinities declined from 32 to 16 mg/l $CaCO_3$, specific conductance from 260 to 86, but calcium at 3 mg/l was relatively stable. Thus over the lst 25 to 30 years the literature has shown the importance of drawdowns for maintaining productivity in waterfowl production areas, and has attributed lower productivity with age to the loss of nutrients.

Drawdowns can be a useful tool for increasing waterfowl use in some impoundments; however, the loss of productivity in aging freshwater impoundments being *caused by nutrient loss is an incorrect concept.*

Let's re-examine the evidence. Whitman's (1976) age-fertility decline also showed chloride declining from 62 to 14 mg/l and sodium declining from 34 to 10 mg/l. He failed to recognize the importance of water

source at his study areas. Sodium and chloride were *the* major cation and anion in solution and occurred at the ratio of 1:1.8. Since this study was located in the Maritime Provinces of Canada, the source of such large concentrations of sodium and chloride can only be sea salt (sea water has a Na:Cl ratio of 1:1.8). I can only conclude that the selection of impoundment age categories was, unfortunately, positively correlated with distance from the Atlantic Ocean.

Kadlec's data was based on 24 samples, only 2 to 6 of them were taken in pre-drawdown, drawdown, or refilled conditions. Though he undoubtedly measured differences, the variability of all 24 samples is well within 2 standard deviations of the summer means shown for comparable nutrients in figures 13-15. Kadlec (1962), as a result of his own work at Backus Lake, Michigan, and in his consideration of DiAngelo's master thesis (1953) on plant succession after flooding projects in Michigan, also concluded that plant succession is responsible for the pattern of waterfowl use. Knighton (1984) defined the important impact of water level fluctuation (and its dependence on water source) on plant succession.

To leave this discussion without direct evidence of the insignificance of drawdowns on nutrient availability would be irresponsible. Many of the misconceptions relating to nutrient availability would never have occurred if water quality studies were conducted year around. Some authors have made winter measurements on either dissolved oxygen or alkalinity but never other nutrients (Lathwell *et al.* 1969, Bouldin *et al.* 1973). The average impact of winter conditions has been illustrated in figures 10, 14 and 15, but the range a particular nutrient takes over winter can only be seen in time plots. All dissolved constituents in impoundment water increase over winter with the exception of oxygen, which decreases. The mechanism causing these increases is associated with a low level of oxygen and caused by a redox potential of 0.2 volts or less. Above a redox potential of 0.2 volts, a thin brown oxidized layer exists at the surface of bottom muds. When the redox potential falls below 0.2 volts the surface muds become reduced, the brown layer turns black, and nutrients dissolve readily into the water (Mortimer 1941, 1942). Much of the nutrient fluctuation in impoundment water during ice-free and ice-covered conditions is the result of organic matter interactions with either bacteria or changes in the redox potential of the environment. Graphs, over time, of total phosphorus, total particulate phosphorus, water level, and general levels of dissolved oxygen can be used to describe the processing of organic matter and nutrients in shallow (less than 2 meters or 6 feet deep) impoundment waters (fig. 16).

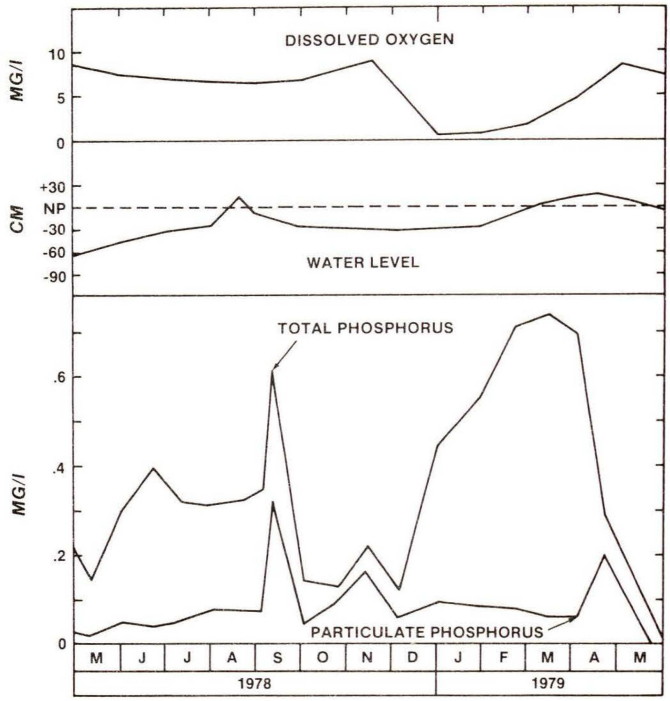

Figure 16.--*Water level, total phosphorus, and total particulate phosphorus in a surface water only shallow water impoundment. The dissolved oxygen is constructed from mean values measured in many impoundments.*

Cuba Impoundment was in a drawdown over the winter of 1977-1978 and was at a water level of 90 cm (3 feet) below normal pool on April 1, 1978. The impoundment filled to normal pool by mid-August. During this time, total and total particulate phosphorus concentrations were not different from summertime values measured under relatively stable water levels. The drawdown and refilling did not affect concentrations of nutrients in the water. During May, June, July, August, and early September, the difference between total and total particulate phosphorus (dissolved phosphorus) was relatively large--a common situation during the summer. In mid-September total and particulate phosphorus levels increased as the result of large organic matter inputs. These inputs probably consisted of a die-off of duckweed and hardwood leaffall. Particulate levels remained a relatively large part of total phosphorus during the fall even though oxygen levels increased in the cold waters.

Ice cover was complete by November 15. Oxygen levels began to fall but even during late November and early December bacteria were working hard to consume organic matter. Sometime in late December the bottom muds became reduced (redox < 0.2 volts) at their surface and very large amounts of nutrients dissolved into the water, coated dead vegetation, and kept

rising in concentration into early April. The ice cover broke in mid-April, and in a matter of 1 or 2 days the waters increased in oxygen, redox at the surface muds rose above 0.2 volts and dissolved nutrients precipitated into the bottom muds. In late April and early May the relatively high particulate phosphorus levels indicate that bacteria were facing a challenge to reduce organic matter loading from upland snowmelt, but had mostly overcome these inputs by late May. Similar curves exist for impoundments with large amounts of groundwater input. Although the fall organic matter peaks are smoothed out in the higher flow situation, the over-winter increases are just as large (fig. 17). Ketchum Impoundment was also at 90 cm. (3 feet) below normal pool in mid-November of 1976 and filled over winter from groundwater inflow.

Drawdowns do not affect water nutrient concentrations any more than normal variation during ice-free periods. All impoundment waters recycle mud nutrients into the water at large concentrations under the ice. This occurs in waters 6 feet deep or less under ice cover whether drawdowns occurred previously or not. Thus drawdown techniques should be based on prescribed needs to alter life-form vegetation patterns and plant-water interspersion, and not for the purpose of recycling nutrients.

The previous discussion applies to ice-covered impoundments in forested areas of the northern Lake States, New York, Vermont, New Hampshire, Maine, and adjacent areas of southern Canada. There are large allocthonous (derived from outside of the impoundment) nutrient inputs to impoundments there and elsewhere that were not measured in the relatively undisturbed forested study areas. These include large amounts of salts derived from oceans in maritime zones, rivers flooding water and nutrient-rich sediment into adjacent wetlands, nutrient-rich waters and sediment from agricultural runoff, dust in dry areas, sewage or irrigation water outfalls, and pumping of groundwater of various qualities to fill wetland basins.

All of these conditions may be responsible for filling a drawn-down impoundment, and may be confounded with a perceived nutrient rejuvenation resulting from the drawdown.

Drawdowns and refilling with indigenous water will cause nutrient concentrations to increase in the water as dried muds and decayed vegetation are dissolved. However, the magnitude of these concentration changes must be put in perspective. They are similar to changes occurring with autumn leaf fall, algae or duckweed die-offs, and evaporation concentration. Nutrient concentrations caused by reduced bottom muds are two to nine times larger and they occur every year. Allocthonous nutrient additions may also be on a scale similar to reduced conditions; both these and reduced mud sources are large compared to drawdown-refilling effects with indigenous water.

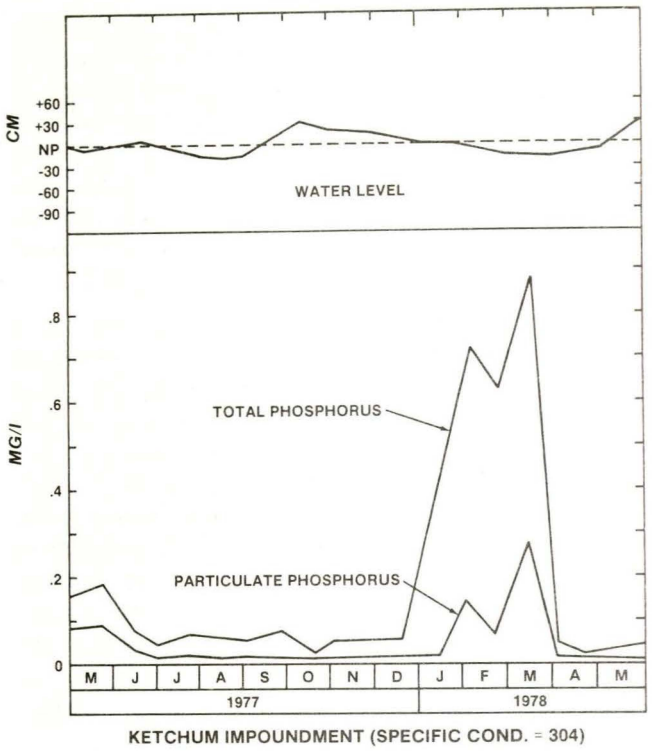

Figure 17.--*Water level, total phosphorus, and total particulate phosphorus in a groundwater dominated shallow water impoundment.*

SUMMARY

Water chemistry is a good indicator of water source (surface, groundwater, or mixtures) and thus the relative amount of water supply. Impounding shallow water areas up to 2 meters deep will increase July maximum temperatures by 5° C above unimpounded streams, but temperatures will be identical to natural marshes and lakes. Releasing water to shaded streams reduces water temperature by 4° C. Dissolved oxygen (DO) fluctuates from less than one mg/l under the ice to super saturated conditions in the spring and fall. Rapid DO changes during the summer restrict fish use. Neither coliform bacteria nor dissolved nutrients exceed State standards for recreational uses or eutrophication. Drawdowns do not recycle large quantities of nutrients in the water, but reduced bottom muds do release large nutrient amounts every year under the ice regardless of water source or timing of drawdowns. Thus water quality is not justified as a reason for drawdowns, but is related to water supply and variations in water level which control vegetative growth.

LITERATURE CITED

Adelman, Ira R.; Smith, Lloyd L. Effect of oxygen and growth on food conversion efficiency of northern pike. The Progressive Fish-Culturist 32(2): 93-96; 1970.

Baldassarre, Guy A. Ecological factors affecting waterfowl production on three man-made flowage in central Wisconsin Stevens Point: University of Wisconsin; 1978. 124 p. M. S. thesis.

Bouldin, D. R.; Lathwell, D. J.; Goyette, E. A.; Lauer, D. A. Changes in water chemistry in marshes over a 12-year period following establishment. New York Fish and Game J. 20(2): 129-146; 1973.

Cook, Arthur H.; Powers, Charles F. Early biochemical changes in the soils and waters of artificially created marshes in New York. New York Fish and Game J. 5(1): 9-65; 1958.

DiAngelo, S. Aquatic plant succession at certain waterfowl flooding projects in Michigan. Ann Arbor, MI: University of Michigan; 1953. 112 p. M. S. thesis.

Hartman, G. F. Management of central Wisconsin flowages. Wisconsin Conserv. Bull. 14: 19-22; 1949.

Hussong, D.; Damare, J. M.; Limpert. R. J.; Sladen, W. J. L.; Weiner, R. M.; Colwell, R. R. Microbial impact of Canada geese (*Branta canadensis*) and Whistling swans (*Cygnus colubianus columbianus*) on aquatic ecosystems. Appl. and Environ. Microbiol. 37(1): 14-20; 1979.

Kadlec, John A. Effects of a drawdown on a waterfowl impoundments. Ecology 43(2): 267-281; 1982.

Knighton, M. Dean. Vegetation management in water impoundments: water-level control. In: Water impoundments for wildlife: a habitat management workshop. Gen. Tech. Rep. NC-100. St. Paul, MN: U. S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1985: 39-50.

Lathwell, D. J.; Mulligan, H. F.; Bouldin, D. R. Chemical properties, physical properties and plant growth in twenty artificial wildlife marshes. NY Fish and Game J. 16(2): 158-183; 1969.

MacNamara, L. G. Potentials of small waterfowl areas. Trans. North Am. Wildl. Conf. 22: 92-96; 1957.

Mortimer, C. H. The exchange of dissolved substances between mud and water in lakes III and IV. J. Ecol. 30: 147-201; 1942.

Mortimer, C. H. The exchange of dissolved substances mud and water in lakes I and II. J. Ecol. 29: 280-329; 1941.

Reid, A. W. Personal communication. Univ. of Missouri; 1982.

Tonn, William M.; Magnuson, John J. Patterns in the species composition and richness of fish assemblages in northern Wisconsin lakes. Ecology 63(4): 1149-1166; 1982.

Verry, Elon S. Selection of water impoundment sites in the Lake States. In: Water impoundments for wildlife: a habitat management workshop. Gen. Tech. Rep. NC-100. St. Paul, MN: U. S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1985: 31-38.

Whitman, W. R. Impoundments for waterfowl. Occas. Pap. 22. Ottawa, ON: Environment Canada, Canadian Wildlife Service; 1976. 22 p.

WETLAND INVERTEBRATES IN RELATION TO HYDROLOGY AND WATER CHEMISTRY

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Mosquito control, especially as a restraint to the vector of malaria and encephalitis, was one justification for drainage of North American wetlands in the early 1900's. The decline of yellow fever and malaria after swamp and marsh drainage associated with the Panama Canal project was often cited to defend agricultural "reclamation" of other "wasteland" wetlands (Nolen 1913).

Today the economic, political, recreational, and scientific values of functioning wetland ecosystems are increasingly recognized (Odum 1978). Unfortunately, vast areas of North American natural wetlands have been lost to agricultural, industrial, and urban developments (Weller 1981). Many remaining wetlands have suffered major perturbations in water quality, hydrologic regime, and habitat isolation. A holistic management philosophy for public wetlands has recently been adopted by most natural resource agencies. These long-term management plans often include restoration of certain drained wetlands. Although the ecological functions of natural wetlands cannot be completely duplicated, water impoundments have proven effective in many wetland restoration programs. Monies from license fees and taxes on hunting and fishing equipment have allowed public acquisition of many wetlands by state and federal agencies.

While the general public has a positive attitude toward wetland birds, mammals, herpetofauna, and fish, their interest has not been expanded to include aquatic invertebrates. Many recent studies have demonstrated that these lower trophic forms are extremely important in maintaining a functional wetland habitat, not only as a protein food base for vertebrates, but also in nutrient cycling (Anderson and Sedell 1979). The purpose of this manuscript is to provide resource personnel with ecological information on both wetland invertebrates and, more specifically, how these organisms may respond to wetland management techniques.

INVERTEBRATE ADAPTATIONS TO HYDROLOGIC CHANGES

Long-term, regional hydrologic cycles have shaped the life history strategies that wetland invertebrates have evolved. Short-term water regimes, physical factors (basin morphology and complex structure), chemical factors (nutrient inputs), and biotic factors (hydrophyte structure and predator density) may, however, determine actual occurrence and abundance at any given time. Present knowledge regarding ecological strategies available to temporary pool invertebrates has been well summarized (Wiggins *et all.* 1980). The basic life history groups from that manuscript are summarized using examples of genera (table 1).

Basic invertebrate adaptations for temporary wetlands include rapid development, marked seasonality in life cycle, and egg or pupal stages that can tolerate drought periods. The groups of Turbellaria (flatworms), Lumbriculidae (freshwater worms), Bryozoa (ectoprocts), Anostraca (fairy shrimp), Conchostreaca (clam shrimp), Cladocera (water fleas), Ostracoda (seed shrimp), Ephemeroptera (mayflies), Chaoboridae (phantom midges), Culicidae (mosquitos), and Sciomyzidae (marsh flies) all contain species with drought resistant egg, ephippia, or statoblast stages. Many organisms demonstrate an obligate diapause (period of non-development) which appears tied to seasonal flooding. Eggs of *Caenestheriella* phyllopeds may remain viable for 5 years under dry conditions (Mattox and Velardo 1950). Some midge larvae construct cocoons during dry periods (Grodhaus 1976). Fairy shrimp are dependent on wetland habitats which remain dry in winter, but reflood in spring (Broch 1965). Other adaptations include self-fertilization in some pulmonate snails and parthenogenetic reproduction in cladocera. As reflooding occurs, *Daphnia pulex* may direct a mere 5 percent of its gross energy

Table 1.--*Invertebrate groups according to life history tolerance or avoidance of drought period and period of recruitment in the community (Wiggens* et al. *1980)*

Group 1--Overwintering residents:
Passive dispersal only.
Examples include *Phagocata, Nais, Helobdella, Daphnia, Cyclops, Procambarus, Hyallela, Asellus, Physa, Gyraulus, Sphaerium.*
(Most oligochaetes, leeches, zooplankton, crayfish, amphipods, isopods, gastropods, pelecypods)
Group 2--Overwintering spring recruits:
Oviposition dependent on water; most reproduce in spring water.
Examples include *Agabus, Haliplus, Hydrobius, Tanytarsus, Chironomus, Tabanus.*
(Some beetles, most midges.)
Group 3--Overwintering summer recruits:
Oviposition independent of water; egg deposition in mud.
Examples include *Lestes, Aedes, Chaoborus.*
(Odonates, mosquitoes, phantom midges.)
Group 4--Non-wintering spring migrants:
Adults leave temporary water before drying; overwintering mostly in permanent water.
Examples inlcude *Sigara, Notonecta, Belostoma, Gerris, Ranatra, Dytiscus,* Gyrinus.
(Most hemipterans, some beetles.)

budget (in excess of maintenance) toward growth, but then spend the remainder in reproductive effort (Richman 1958).

Behavioral adaptations to drying conditions may include burrowing in sediments, moving toward deeper water or emigrating from the basin. Leeches, oligochaetes, clams, and crayfish may burrow into the water table to avoid desication. Imago beetles and hemipterans demonstrate well developed flight dispersal in relation to water drawdown (Fernado 1958). This migration strategy requires high energy food for flight and, correspondingly, a reduced fecundity. Physical conditions, such as exposed mudflats or increased prey are necessary for such flight, but behavioral interaction with species that are competitors or predators may influence the timing of these movements. Movements may involve only a short flight within a wetland complex to another basin or may extend 80 km or more (Popham 1964).

Food availability and developmental potential are determined by the extent and duration of flooding. Invertebrates that have adapted to such fluctuating conditions demonstrate diverse trophic and developmental strategies. Figure 1 represents the response of four common freshwater invertebrate genera to five separate annual hydrologic regimes in a mid-latitude North American wetland. None of the represented hydrologic regimes meets all the requirements for all four of these common organisms. The adaptive timing of reproduction is based on genetic potential, physiological condition, and habitat availability. The specificity of a population's breeding schedule varies between species, but a wide range of schedules and high fecundity allow for greater success in a fluctuating aquatic environment.

WATER CHEMISTRY AND INVERTEBRATE-HYDROPHYTE ASSOCIATION

As wetland waters fluctuate, ions and nutrients may concentrate or become dilute. These chemical changes influence the richness of invertebrate species, abundance, growth, and behavior. Temperature and oxygen levels seem to have the most pronounced effects. Temperature directly affects metabolic activity. Timing of molt (voltinism), feeding activity, emergence patterns, and hatching are all influenced by water temperature. Turbellaria require temperatures above 5° C to stimulate egg development and above 8° C for hatching (Young 1974). *Phagocata* (flatworms) will fragment into resistant cysts at high temperatures (Castle 1928).

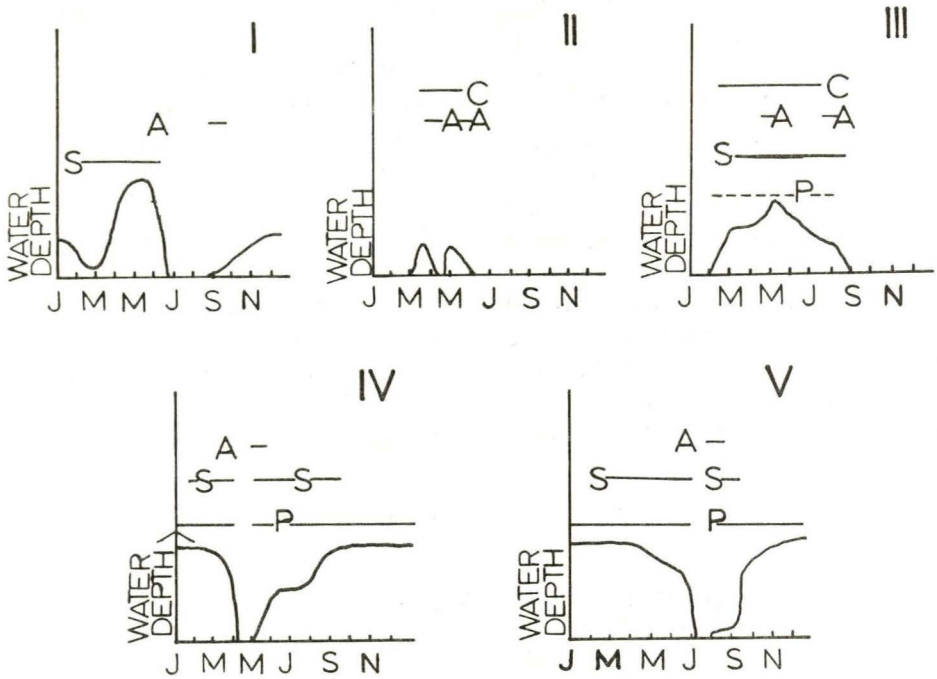

Figure 1.--*Response of four wetland invertebrates (P-*Physa *snail, S-*Sigara *corixid, A-*Aedes *mosquito and C-*Chirocephalopsis *fairy shrimp) to five separate mid-latitude, emergent wetland basins under various annual hydrologic regimes. I-Autumnal Basin, II-Short Vernal Basin, III-Long Vernal Basin, IV-Moist Soil Early Drawdown, V-Moist Soil Late Drawdown. Dashed line indicates occurrence only if pioneering occurs. Letters indicate period of oviposition. (After Wiggens* et al. *1980, Broch 1965, Reid* et al. *in prep.)*

Fairy shrimp are not only dependent on fluctuating water conditions, but fall egg development is stimulated by decreasing temperatures and high oxygen levels. As spring flooding occurs and oxygen levels drop as hydrophytes decompose, the fairy shrimp hatch (Broch 1965). Many other organisms require a strict progression of rising temperatures (Danks 1971). The hatching stimulus for the water flea *Diaptomus stagnalis* is controlled by decreased oxygen levels (Brewer 1964), while the hatching of the playa shrimp *Branchinecta mackini* is controlled by 0_2 tension and percent salinity (Brown and Carpelan 1971). Populations of Molluscs are not large in impoundments in the forested Lake States if calcium and magnesium needed for shell development are low (less than 50 micromhos specific conductance) (Verry, personal communication; Baldassare 1978).

As water fluctuations influence chemical composition of waters, they also influence hydrophyte germination (van der Valk and Davis 1980). One of the earliest recognized habitat relationships for aquatic invertebrates was that with aquatic plants. Hydrophyte leaf shape, structure, and surface area are related to invertebrate abundance (Wieser 1951, Rosine 1955). Several investigators (Krecker 1939, Andrews and Hasler 1943, Krull 1970) have found higher densities of insects associated with aquatic plants containing highly dissected leaves.

Hydrophyte conditions are not stable and changes in growth and senescence influence the invertebrates associated with them. Annual fluctuations in the amphipod *Hyallela azteca* associated with *Chara* and smartweed *Polygonum* can occur, as seen in a shallow Colorado lake (Rosine 1955). The largest standing biomass of invertebrates in Mississippi wetlands occurred in association with coontail *Ceratophyllum* and fanwort *Cabomba* (Teels *et al. 19176).* These submergents become established only after flooding and after resulting turbidity has subsided. Investigations of Lake Erie waters revealed that "thrifty" (or healthy) plants maintain the greatest invertebrate abundance (Krecker 1939). Smartweed leaf drop associated with drought stress and reflooding resulted in a depauparate invertebrate fauna the following spring in a Mississippi River floodplain wetland (Reid *et al.* in prep.).Community composition is dependent on plant condition and food habits of the invertebrates. Seasonal senescence of emergents encourages colonization by detritivore communities (Danell and Sjoberg 1979). Biochemical inhibitors from submergents may

influence associated periphyton (Abdel-Malek 1948) and invertebrate feeding, growth, and hatching. Annual periphyton shifts (Young 1945, Millie 1979) undoubtedly influence grazer community composition.

Despite the wide deversity of species present in most natural or impounded wetlands, certain taxonomic groups are usually dominant. Although techniques and sampling periods vary among studies, chironomids or freshwater worms are usually the most numerous in shallowly flooded emergent wetlands or typical littoral regions of eutrophic lakes (table 2). Dipterans are the most numerous of emerging insects, while mayflies and odonates are somewhat less numerous. In Ontario wetlands 87 and 98 percent of all emerging adult insects were dipterans (Judd 1953, 1958, 1960) and chironomids and culicids dominated the species composition. Snails, mayflies, corixids, and amphipods may form the next most common aquatic groups. Impounded water with minimal hydrologic modifications or shallow lakes may encourage submergent hydrophyte growth and associated amphipods (Cooper 1965, Whitman 1976). Invertebrate production may be less than in seasonally fluctuating wetlands.

Forested wetlands contain a very different community structure than emergent marshes. Fingernail clams *(Sphaerium* and *Musculium)* make up between 58 and 98 percent of invertebrate biomass in Mississippi and Alcovy River floodplain samples (Eckblad *et*

Table 2.--*Dominant macroinvertebrates in selected shallowly flooded, emergent wetlands*[1]

Organisms	Percent of sample	Reported form	Site	Source
Chironomidae Oligochaeta	80.1 19.9	N[2]	North Slope, AK, USA	Bergman *et al.* 1977
Gastropoda *(Helisoma/Physal)* Chironomidae Oligochaeta	36.2 19.1 17.6	N	Lizard Lake, IA, USA	Tebo 1955
Chironomidae Planorbidae Corixidae	70.4 20.3 8.0	N	< 1 yr age Managed wetlands NB, CAN	Whitman 1974
Chironomidae Gastropoda Planorbidae Physidae Lymnaeidae Corixidae	42.5 46.5 (22.5) (6.5) (17.4) 6.2	N	1-4 yr age Managed wetlands	Whitman 1974
Chironomidae Planorbidae Corixidae Talitridae	61.9 6.2 13.1 7.9	N	7 + yrs Managed wetlands NB, CAN	Whitman 1974
Chironomidae Planorbidae Corixidae Talitridae	60.2 9.3 6.8 7.0	N	NB, CAN	Whitman 1974
Tanytarsus (Chironomidae) + *Hyalella* (Talitridae)	74/54	N/V	S. Michigan Lake MI, USE	Anderson and Hooper 1956

[1]Data does not include zooplankton (Cladocera, Copopoda, Ostracoda).
[2]N = numbers, V = volume.

al. 1977, Parsons and Wharton 1978). *Asellus* isopods, *Cranonyx* amphipods, fingernail clams, and crayfish dominated the invertebrates of lowland hardwood forests of Louisiana, Illinois, and Missouri (Moore 1970, Hubert and Krull 1973, White, 1982).

MANAGEMENT IMPLICATIONS

Although water manipulation is a common tool for wetland management, little is known about its effect on macroinvertebrate ecology (Weller 1978). A dramatic decrease in invertebrate abundance after a drawdown was noted in a Michigan wetland (Kadlec 1962). Herbivores decreased, but predator species increased in another drawdown (Wegener *et al.* 1974). The species diversity of an aquatic invertebrate community dropped rapidly in natural wetlands of Minnesota just prior to drying (Hohman1977). Available biomass during drawdown depends on emigration or aestivation tactics. Most of the information related to drawdown has not considered semi-aquatic organisms such as *Stenus* rove beetles or *Pirata* spiders. These organisms rapidly respond to mudflat conditions and may greatly increase biomass estimates. Response to artificial, shallow flooding is also rapid, especially if timed to natural hydrologic increases and invertebrate growth and hatching strategies. Invertebrate abundance was greatest 6 weeks after Green Tree reflooding (Hubert and Krull 1973).

The duration of flooding influences invertebrate occurrence. Semi-permanent wetlands appeared more productive than seasonal basins in Minnesota (Hohman 1977). Whitman (1974) found 1.5-5 years as optimal for invertebrate production on shallow impounded water of Nova Scotia, while Reinecke (1977) found the greatest abundance and biomass of invertebrates in 3- to 5-year-old beaver ponds. Highly turbid waters will restrict the development of submergents, and if the basin is flooded to depths greater than a few centimeters, the area will rapidly decline in invertebrate usage. Seasonal or semi-seasonal wetlands may be most productive where input waters are highly turbid.

The relationship between invertebrates and vegetation suggests there may be major faunal shifts with vegetation succession. Voights (1976) documented this shift in summer studies of Iowa marshes. Isopod and snail biomasses increased as emergent and dead vegetation increased, while midges cladocera, and copepods dominated more open areas and amphipods increased in dense beds of submerged vegetation. The number of organisms, biomass, and number of taxa all increased when the ratio of cover: water approached 50:50 at the Delta Marsh in Manitoba (Kaminsl 1979).

Investigations related to physical treatments (mow ing, disking, burning) are few. At the Delta Marsl mean number of invertebrates was greater on the cor trol site than on mowed or rototilled sites after sprin reflooding, but mowed sites showed higher numbers year later (Kaminski 1979). Density, biomass and tax richness of aquatic invertebrates increased dramat cally 4 weeks after cattails (*Typha latifolia)* were cu and removed from plots in southern Manitoba (Mu kih *et al.* 1982). Early fall flooding may produce greate invertebrate numbers in disked areas because of th conditoned plant material (Reid *et al.* in prep.). Mos numerous at these sites will be highly mobile aquati forms (Hydrophilidae, Dytiscidae) or larvae of emer gent forms (Culicidae, Ephyridae).

The importance of wetland invertebrates to avai omnivores has been documented only recently (Chur 1961; Sugden 1973; Swanson and Meyer 1973, 197 Taylor 1977). Because impounded waters are ofte managed principally for these predators, it is impor tant to know where and how exploitation occurs. Th broad term "aquatic invertebrate" has masked the d versity of life history strategies and wetland basir utilized by these prey organisms. Breeding pintai concentrate on chironomids and snails in shallo potholes (Krapu 1974); white-winged scoters feed ex clusively on the amphipod *Hyalella azteca* in semi-pe manent lakes (Brown 1981); wood ducks ea amphipods, isopods, and snails of lowland hardwoo forests (Drobney 1977); while migratory sora feed o semi-aquatic beetles and grasshoppers (Rundle 1980 Variation in emergence and egg laying dates withi single insect genera (Meyer and Swanson 1982) allo for potential vertebrate predation over an extende period. Predators may select certain basins becau the presence or conditions of plants save as a prox mate cue to invertebrate prey. Availability of prey o ganisms initially increases with decreasing wat levels, provided the invertebrates do not emigrat Predators shift to wetland basins where the least e ergy is expended to forage.

Invertebrate mortality of 84 percent (Schneid 1978) and up to 90 percent (Schneider and Harringto 1981) has been reported on intertidal mudflats. Wa ing birds reduced fish biomass by 76 percent in drying Florida wetland (Kushlan 1976). Invertebrat with low mobility and emigration tactics are most vu nerable when interior marshes dry in mid- to late sur mer. The behavior of predators may also chan (Swanson and Sargent 1972, Watmough 1978) as fo aging efficiency increases. Not only the numbers

prey, but the caloric and nutrient value of prey to the predators should be considered in management options (Driver 1981).

IMPORTANCE AND PROBLEMS OF WETLAND DATA INTERPRETATION

Wetland invertebrates were first considered important in diets of obligate animal predators. Recent food habit studies have shown that invertebrates are highly utilized during critical physiological periods of many vertebrate omnivores. Aquatic invertebrates are also important in vegetative decomposition and processing of nutrients in aquatic systems.

Several problems with wetland invertebrate investigations should be considered when evaluating research for management. Shallow water bodies, often typified by dense stands of emergent vegetation, present a challenge to organism collection. Several techniques have recently been developed or modified (Lammers 1977, Swanson 1978a, 1978b, LeSage and Harrison 1979) by wetland investigators. Different mesh sizes among studies makes direct comparisons of density and production data difficult. The few quantitative studies that deal directly with shallow-impounded wetlands or wetland techniques restrict viable options available to managers. In addition, many of these studies were conducted using broad systematic descriptions of organisims, such that trophic relationships or species life history strategies are impossible to determine. Considering the richness of invertebrate species in wetlands and the myriad of adaptations they employ to deal with water fluctuations, ecological projections based on taxonomic groupings above the level of family or genus are probably suspect.

CONCLUSIONS

Long-term hydrologic cycles have shaped the life history tactics of wetland invertebrates. This diverse group exhibits a wide range of feeding and reproductive strategies in association with dynamic water chemistry and vegetation patterns. The manipulation of water basins will directly influence availability of aquatic habitat and indirectly affect invertebrates through the physiological responses of hydrophytes. Wise, ecologically-based decisions will yield productive wetland systems.

Aquisition of potentially impounded wetlands should favor restoration of natural wetland areas which have been degraded. Construction should emphasize a complex of wetland types which may include green tree and seasonally flooded emergent types. Wetland management should strive to emulate water fluctuations of the region because invertebrates have adapted to such dynamic conditions. The degree and timing of fluctuations depends on desired species composition. Fall flooding will stimulate the hatch of many species and larval forms may continue to develop over the winter. Our present knowledge of water manipulations suggests that management for specific hydrophyte communities may be the most practical means of increasing invertebrate production. A diversity of plants with high seed production, as well as plants with finely dissected leaves may result from integrated management. Inflow water should be monitored for pesticides and pollutants. Management should strive for pesticide education in urban wetland areas because mosquito or agricultural pest control measures may be highly detrimental to wetland invertebrate survival or growth.

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LITERATURE CITED

Abdel-Malek, A. Plant hormones (auxins) as a factor in the hatching of *Aedes trivittaus* (Coquillett) eggs. Ann. Ent. Soc. Am. 41: 51-57; 1948.

Anderson, N. H.; Sedell, J. R. Detritus processing by macroinvertebrates in stream ecosystems. Ann. Rev. Entomol. 24: 351-377; 1979.

Anderson, R. O.; Hooper, F. F. Seasonal abundance and production of littoral bottom fauna in a southern Michigan lake. Trans. Am. Micro. Soc. 75: 259-270; 1956.

Andrews, J. D.; Hasler, A. D. Fluctuations in the animal populations of the littoral zone in Lake Mendota. Trans. Wis. Acad. Sci., Arts and Lett. 35: 175-185; 1943.

Baldassarre, G. A. Ecological factors affecting waterfowl production on three man-made flowages in central Wisconsin. Stevens Point, WI: University of Wisconsin; 1978. 124 p. M.S. thesis.

Bergman, R. D.; Howard, R. L.; Abraham, K. F.; Weller, M. W. Water birds and their wetland resources in relation to oil development at Storkerson Point, Alaska. Resour. Publ. 129. Washington, DC: U.S. Fish and Wildlife Service; 1977: 1-38.

Brewer, R. H. The phenology of *Diaptomus stagnalis* (Copepoda: Calonoida): the development and the hatching of the egg stage. Physiol. Zool. 37: 1-20; 1964.

Broch, E. S. Mechanism of adaptation of the fairy shrimp *Chirocephalopsis bundyi* Forbes to the temporary pond. Cornell Univ. Agric. Exp. Sta. Mem. 392: 1-48; 1965.

Brown, L. R.; Carpelan, L. H. Egg hatching and life history of a fairy shrimp *Branchinecta mackini* Dexter (Crustacea: Anostraca) in a Hohave Desert playa (Rabbit Dry Lake). Ecology 52: 41-54; 1971.

Brown, P.W. Reproductive ecology and productivity of white-winged scoters. University of Missouri; 1981. 175 p. Ph.D. dissertation.

Castle, W. A. An experimental and histological study of the life-cycle of *Planaria velata.* J. Exp. Zool. 51: 417-483; 1928.

Chura, N. J. Food availability and preferences of juvenile mallards. Trans. North Am. Wildl. and Nat. Res. Conf. 26: 121-134; 1961.

Cooper, W. E. Dynamics and productions of a natural population of a freshwater amphipod, *Hyalella azteca.*Ecol. Monogr. 35: 377-394; 1965.

Danell, K.; Sjoberg, K. Decomposition of *Carex* and *Equisetum* in a northern Swedish lake: dry weight loss and colonization by macroinvertebrates. J. Ecol. 67: 191-200; 1979.

Danks, H. V. Overwintering of some north temperate and arctic chironomidae. II. Chironomid biology. Can. Entomol. 103: 1875-1910; 1971.

Driver, E. A. Caloric values of pond invertebrates eaten by ducks. Freshwater Biol. 11: 579-582; 1981.

Drobney, R. D. The feeding ecology, nutrition and reproductive bioenergetics of wood ducks. University of Missouri; 1977. 170 p. Ph.D. dissertation.

Eckblad, J. W.; Peterson, N. L.; Ostlie, K.; Temte, A. The morphometry, benthos, and sedimentation rates of a floodplain lake in pool 9 of the Upper Mississippi River. Am. Midl. Nat. 97: 433-443; 1977.

Fernando, C. H. The colonization of small freshwater habitats by aquatic insects. I. General discussion, methods and colonization in the aquatic coleoptera. Ceylon J. Sci. 1: 117-154; 1958.

Grodhaus, G. Two species of *Phaenopsectral* with drought resistant larva (Diptera: Chironomidae). J. Kansas Entomol. Soc. 49: 405-418; 1976.

Hohman, W. L. Invertebrate habitat preferences in several contiguous Minnesota wetlands. University of North Dakota; 1977. 81 p. M.S. thesis.

Hubert, W. A.; Krull, J. N. Seasonal fluctuations of aquatic macroinvertebrates in Oakwood Bottoms Greentree Reservoir. Am. Midl. Nat. 90: 351-364; 1973.

Judd, W. W. A study of the population of insects emerging as adults from the Dundas Marsh, Hamilton, Ontario, during 1948. Am. Midl. Nat. 49: 801-824; 1953.

Judd, W. W. Studies of the Byron Bog in southwestern Ontario. IX. Insects trapped as adults emerging from Redmond's Pond. Can. Entomol. 90: 623-627; 1958.

Judd, W. W. A study of the population of insects emerging as adults from South Walter Pond, Ontario. Am. Midl. Nat. 63: 194-210; 1960.

Kadlec, J. A. Effects of a drawdown on a waterfowl impoundment. Ecology 43: 267-281; 1962.

Kaminski, R. M. Dabbling duck and aquatic invertebrate responses to manipulated wetland habitat. Michigan State University; 1979. 62 p. Ph.d. dissertation.

Krapu, G. L. Feeding ecology of pintail hens during reproduction. Auk 91: 278-290; 1974.

Krecker, F. H. A comparative study of the animal populations of certain submerged aquaitic plants. Ecology 20: 553-562; 1939.

Krull, J. N. Aquatic plant macroinvertebrate associations and waterfowl. J. Wildl. Manage. 34: 707-718; 1970.

Kushlan, J. A. Wading bird predation in a seasonally fluctuating pond. Auk 93: 464-476; 1976.

Lammers, R. Sampling insects with a wetland emergence trap: design and evaluation of the trap with preliminary results. Am. Midl. Nat. 97: 381-389; 1977.

LeSage, L.; Harrison, A. D. Improved traps and techniques for the study of emerging aquatic insects. Entomol. News 90: 65-78; 1979.

Mattox, N. T.; Velardo, J. T. The effect of temperature on the development of the eggs of a conchostracan phyllopod *Caenestheriella gynecial.* Ecology 31: 497-506; 1950.

Meyer, M. I.; Swanson, G. A. Mosquitoes (Dipthera: Culicidae) consumed by breeding Anatidae in south central North Dakota. Prairie Nat. 14: 27-31; 1982.

Millie, D. F. The epiphytic diatom flora of three Lake Erie marshes. Bowing Green University; 1979. 205 p. M.S. thesis.

Moore, W. G. Limnological studies of temporary ponds in southeastern Louisiana. Southwest. Nat. 15: 83-110; 1970.

Murkin, H. R.; Kaminski, R. M.; Titman, R. D. Responses by dabbling ducks and aquatic invertebrates

to an experimentally manipulated cattail marsh. Can. J. Zool. 60: 2324-2332; 1982.

Nolan, J. H. Missouri's swamp and overflowed lands and their reclamation. Report to 47th Missouri General Assembly. Hugh Stephens Printing Co.; 1913. 141 p.

Odum, E. P. The value of wetlands: a hierarchical approach. In: Greson, P. E.; Clark, J. R.; Clark, J. E., eds. Wetland functions and values: the state of our understanding. MN: Am. Water Resour. Assoc., 1978; 16-25.

Parsons, K.; Wharton, C. H. Macroinveterbrates of pools on a Piedmont river floodplain. Ga. J. Sci. 36: 25-33; 1978.

Popham, E. J. The migration of aquatic bugs with species reference to the Corixidae (Hemiptera:Heteroptera). Arch. Hydrobiol. 60: 450-496; 1964.

Reinecke, K. J. The importance of freshwater invertebrates and female energy reserves for black ducks breeding in Maine. Orno, ME: University of Maine; 1977. 113 p. Ph.d. dissertation.

Richman, S. The transformation of energy by *Daphnia pulex*. Ecol. Monogr. 28: 273-291; 1958.

Rosine, W. N. The distribution of invertebrates on submerged aquatic plant surfaces in Muskee Lake, Colorado. Ecology 36: 308-314; 1955.

Rundle, W. D. Management, habitat selection and feeding ecology of migrant rails and shorebirds. University of Missouri; 1980. 228 p. M.S. thesis.

Schneider, D. Equalization of prey number by migratory shorebirds. Nature 271: 353-354; 1978.

Schneider, D.; Harrington, B. A. Timing of shorebird migration in relation to prey depletion. Auk 98: 801-811; 1981.

Swanson, G. A. A water column sampler for invertebrates in shallow wetlands. J. Wildl. Manage. 42: 670-672; 1978a.

Swanson, G. A. Funnel trap for collecting littoral aquatic invertebrates. Progr. Fish Cult. 40: 73; 1978b.

Swanson, G. A.; Meyer, M. I. The role of invertebrates in the feeding ecology of Anatine during the breeding season. Waterfowl Habitat Manage. Symp., Moncten, N.B. 1973. 306 p.

Swanson, G. A.; Meyer, M. I. Impact on fluctuating water levels on feeding ecology of breeding blue-winged teal. J. Wildl. Manage. 41: 426-433; 1977.

Swanson, G. A.; Sargent, A. B. Observation of nighttime feeding behavior of ducks. J. Wildl. Manage. 36: 959-961; 1972.

Sugden, L. S. Feeding ecology of pintail, gadwall, American wigeon and lesser scaup ducklings. Can. Wildl. Serv. Rep. Ser. 24; 1973.

Taylor, T. S. Avian use of moist soil impoundments in southeastern Missouri. University of Missouri; 1977. 98 p. M.S. thesis.

Tebo, L. B. Bottom fauna of a shallow eutrophic lake, Lizard Lake, Pocahontas County, Iowa. Am. Midl. Nat. 54: 89-103; 1955.

Teels, B. M.; Anding, G.; Arner, D. H.; Norwood, E. D.; Wesley, D. E. Aqautic plant, invertebrate and waterfowl associations in Mississippi. Proc. SE Assoc. Game Fish Comm. 30: 610-616; 1976.

van der Valk, A. G.; Davis, C. B. The role of seed banks in the vegetation dynamics of prairie glacial marshes. Ecology 59: 322-335; 1978.

Voights, D. K. Aquatic invertebrate abundance in relation to changing marsh conditions. Am. Midl. Nat. 95: 313-322; 1976.

Watmough, B. R. Observations on nocturnal feeding by night herons *Nycticorax nycticorax*. Ibis 120: 356-358; 1978.

Wegener, W.; Williams, V.; McCall, T. D. Aquatic macroinvertebrates responses to an extreme drawdown. Proc. SE Assoc. Game Fish Comm. 28: 126-144; 1974.

Weller, M. W. Management of freshwater marshes for wildlife. In: Good, R. E.; Whighan, D. F.; Simpson, R. L., eds. Freshwater wetlands: ecological processes and management potential. Academic Press, New York 1978: 267-284.

Weller, M. W. Estimating wildlife and wetland losses due to drainage and other perturbations. In: Richardson, B., ed. Selected proceedings of the Midwest Conference on wetland values and management; Minneapolis, MN: June 1981 Minnesota Water Planning Board, Water Resources Research Center, University of Minnesota; Upper Mississippi River Basin Commission 1981: 337-346.

White, D. C. Leaf decomposition, macroinvertebrate production and wintering ecology of mallards in Missouri lowland hardwood wetlands. University of Missouri; 1982. 293 p. M.S. Thesis.

Whitman, W. R. Impoundments for waterfowl. Occas. Pap. 22: Ottawa, ON: Canadian Wildlife Service; 1976: 6-21.

Wieser, W. Über die quantitative Bestimmung der algenbewohnenden Mikrofauna felsiger Meeresküsten. Oikos 3: 124-131; 1951.

Wiggins, G. B.; Mackay, R. J.; Smith, I. M. Evolutionary and ecological strategies of animals in annual temporary pools. Arch. Hydrobiol./Suppl. 58: 97-206; 1980.

Young, J. O. The occurrence of diapause in the egg stage of the life cycle of *Phaenocora typhlops* Vehdovsky (Turbellaria:Neorhabdocoela). J. Anim. Ecol. 43: 719-731; 1974.

Young, O. W. A limnological investigation of periphyton in Douglas Lake, Michigan. Trans. Am. Micro. Soc. 64: 1-20; 1945.

WILDLIFE OCCURRENCE IN WATER IMPOUNDMENTS

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Impoundments can provide valuable wildlife habitat in all parts of the Lake States. They are important in the northern forested region where productive wetland habitats are scarce. In the prairie region they are important during drought years when natural wetlands dry up. They are especially important in agricultural areas where they mitigate the loss of natural wetlands through drainage.

Many species of wildlife benefit from the construction of impoundments. Among these are moose, white-tailed deer, black bear, waterfowl, rails, and common snipe. Whitman (1976) noted that as impoundments were flooded, the waterfowl brood populations on adjacent natural wetlands rapidly decreased. They can be important to endangered, threatened, or sensitive species such as fisher, common loon, bald eagle, and osprey. Impoundments are also used by furbearers or wetland mammals such as red fox, muskrat, raccoon, beaver, river otter, mink, and northern watershrew. Many nongame birds use the impoundments, including waders, raptors, shorebirds, kingfishers, and wetland passerines. In addition, many of the Lake State reptiles and most of the amphibians are associated with wetland habitats (Probst *et al.* 1983, Crider 1979).

A number of studies (Boyer and Devitt 1961, Beule 1979, Whitman 1976) have shown that during the first year after reflooding there is an increase in the density and diversity of birds. These increases can be attributed to increased edge, interspersion, productivity, nest cavities, or perch sites present in the new impoundments. Aerial foragers (bats and birds) benefit from the impoundment openings in forested regions and the abundance of insect prey. Trees, flooded and killed by the impounded waters, provide nest cavities for waterfowl, some mammals, and several passerine birds. Flooded timber and snags provide a foraging substrate for nuthatches, creepers, and woodpeckers and serve as perches for raptors, kingfishers, and insectivorous hawkers such as flycatchers (Probst *et al.* 1983).

Other papers in this workshop will cover specific impoundment management techniques. The purpose of this paper is to describe how wildlife species and groups are affected by various habitat types and management prescriptions.

VERTEBRATE SPECIES OF IMPOUNDMENTS

We divided the Lake States into four geographic regions that broadly correspond to species' ranges. The northern region includes the forests and bogs of northern Minnesota, Wisconsin, the Upper Peninsula of Michigan, and the northern part of lower Michigan. The southern agricultural region of croplands, pastures, and scattered woodlots encompasses the southern halves of Minnesota and Wisconsin. Our third division is the prairie region of western Minnesota where some western species occur. The fourth region is the southern half of lower Michigan which includes the range of several species not found elsewhere in the Lake States. We noted the occurrence of bird species by region and classified each species as either Permanent resident (P), Summer visitor or breeder (S), Migrant (M), or Winter visitor (W). The occurrence of mammals and herpt species are simply noted by region (table 1).

Birds

About 290 species of birds are regularly found in the Lake States either permanently or seasonally. Of these, 100 inhabit wetlands and another 80 or so are attracted to wetland edges. About a dozen species are found only west of the prairie border of Minnesota.

In our survey of 10 impoundments on the Chippewa National Forest (Probst *et al.* 1983) we recorded 138 bird species, 32 of which were not observed by Kirby (1975) on or near beaver flowages in the same forest. The major difference between these studies was the increased diversity and number of shorebirds found in impoundments. This increase was due to the extensive mudflats around managed impoundments in late summer.

Table 1.--*Resident status of vertebrates by geographical region*

Birds	North	South	Prairie	Lower Michigan
+ Com. loon	S	M	M	M
+ Horned grebe	S	M	M	M
+ Eared grebe			S	
+ Pied-billed grebe	S	S	S	S
+ Red-necked grebe	S	M	S	M
+ Western grebe			S	
+ D.C. cormorant	S	M	S	M
+ Whistling swan	M	M		M
+ C. goose	M/S	M/S	M/S	M
+ Black duck	S	W		P
+ Gadwall			S	
+ Mallard	S	P	S/P	P
+ Pintail	M	M	S	M
+ Wigeon	S	M	M	M
+ Wood duck	S	S	S	S
+ Shoveler			S	
+ B. W. teal	S	S	S	S
+ G. W. teal	S	M	S	M
+ Canvasback		M	S	M
+ Redhead		M	S	M
+ Ring-necked duck	S	M	M	M
+ L. scaup	M	M	S	M
+ G. scaup	M	M	M	M
+ C. goldeneye	S	W	-	W
+ Bufflehead	M	M	M	M
+ Ruddy duck			S	
+ C. merganser	S	M	M	M
+ Red-breasted merganser	S	M	M	M
+ Hooded merganser	S	S	S	S
+ Coot	S	S	S	S
+ C. gallinule		S		S
+ White pelican			S	
+ Herring gull	S	M	M	M
+ Ring-billed gull	M	M	local	M
+ Franklins gull			S	
+ Bonapartes gull	M	M	M	M
+ Common tern	S	M	M	M
+ Forsters tern		M	S	M
+ Black tern	S	S	S	S
+ Great blue heron	S	S	S	S
+ Little blue heron		S		S
+ Great egret		S		local
+ Cattle egret		S		local
+ Black-crowned night heron		S	S	S
+ Yellow-crowned night heron		S		local
+ Green heron		S	S	S
+ Least bittern	S	S	S	S
+ Am. bittern	S	S	S	S
+ Sandhill crane		M	M	M

(Table 1 continued next page)

(Table 1 continued)

Birds	North	South	Prairie	Lower Michigan
+ Virginia rail	S	S	S	S
+ King rail		S		S
+ Black rail		S		S
+ Yellow rail	S			
+ Sora	S	S	S	S
+ Avocet			S	
+ Black-bellied plover	M	M	M	M
+ Lesser golden plover	M	M	M	M
+ Ruddy turnstone	M	M	M	M
+ Semi-palmated plover	M	M	M	M
+ Killdeer	S	S	S	S
+ Am. woodcock	S	S		S
+ C. snipe	S	S	S	S
+ S. B. dowitcher	M	M	M	M
+ L. B. dowitcher	M	M	M	M
+ Hudsonian godwit			M	
+ Marbled godwit		M	S	
+ Whimbrel	M	M	M	M
+ Willet		M	M	
+ Greater yellowlegs	M	M	M	M
+ Lesser yellowlegs	M	M	M	M
+ Solitary sandpiper	M	M	M	M
+ Sanderling	M	M	M	M
+ Upland sandpiper	S	S	S	S
+ Buff-breasted sandpiper			M	
+ Pectoral sandpiper	M	M	M	M
+ Stilt sandpiper			M	
+ Dunlin sandpiper	M	M	M	M
+ Spotted sandpiper	S	S	S	S
+ Least sandpiper	M	M	M	M
+ Semi-palmated sandpiper	M	M	M	M
+ Western sandpiper	M	M	M	M
+ White-rumped sandpiper	M	M	M	M
+ Baird's sandpiper			M	
+ Wilson's phalarope		M	S	
+ Northern phalarope	M	M	M	M
Ruffed grouse	P	P	P	P
Ring-necked pheasant		P	P	P
+ N. harrier	S	P	S	P
Red-tailed hawk	S	P	S	P
Red-shouldered hawk		S/P		S
Rough-legged hawk	M	W	W	W
+ Bald eagle	S	W		W
+ Osprey	S	M		S/M
Peregrine falcon	M	M	M	M
Am. kestrel	S	P	S	P
Short-eared owl	S	P	S/P	P
Great-horned owl	P	P	P	P
Barred owl	P	P	P	P

(Table 1 continued next page)

(Table 1 continued)

Birds	North	South	Prairie	Lower Michigan
Great gray owl	P/W			
Snowy owl	W			
Hawk owl	P/W			
C. nighthawk	S	S	S	S
R. T. hummingbird	S	S	S	S
+ B. kingfisher	S	P/S	S	P/S
Red-headed woodpecker	S	P	S	P
Common flicker	S	P	P	P
Red-bellied woodpecker		P		P
Downy woodpecker	P	P	P	P
Hairy woodpecker	P	P	P	P
Black-backed 3-toed woodpecker	P			
Yellow-bellied sapsucker	S	P		P
Pileated woodpecker	P	P		P
E. kingbird	S	S	S	S
W. kingbird			S	
E. phoebe	S	S	S	S
Olive-sided flycatcher	S			
Yellow-bellied flycatcher	S	M		
Willow flycatcher		S	S	S
+ Alder flycatcher	S	M		M
Cliff swallow	S	S	S	S
Barn swallow	S	S	S	S
+ Tree swallow	S	S	S	S
Rough-winged swallow	S	S	S	S
Bank swallow	S	S	S	S
Chimney swift	S	S	S	S
Crow	S	P	P	P
Raven	P			
Gray-jay	P			
White-breasted nuthatch	P	P	P	P
Red-breasted nuthatch	P	W	W	W
Brown creeper	P	W	W	W
Winter wren	S			
+ Long-billed marsh wren	S	S	S	S
+ Short-billed marsh wren	S	S	S	S
Gray catbird	S	S	S	S
N. shrike	W	W		W
Cedar waxwing	P	P		P
Prothonotary warbler		S		S
N. parula warbler	S			
Black-throated blue warbler	S			
Magnolia warbler	S	M		M
Yellow-rumped warbler	S	M		M

(Table 1 continued next page)

(Table 1 continued)

Birds	North	South	Prairie	Lower Michigan
Canada warbler	S	M		M
Chestnut-sided warbler	S	S		S
Bay-breasted warbler	S	M		M
Am. redstart	S	S		S
Prairie warbler				S
Palm warbler	S	M		M
+ Yellow warbler	S	S		S
Tennessee warbler	S	M		M
Orange-crowned warbler	M	M		M
Wilson's warbler	M	M		M
Golden-winged warbler	S	S		S
Nashville warbler	S	M		M
Connecticut warbler	S	M		M
Mourning warbler	S	M		S/M
+ C. yellowthroat	S	S		S
+ N. waterthrush	S	M		M
Louisiana waterthrush		S		S
+ Red-winged blackbird	S	P		P/S
+ Yellow-headed blackbird	S	S	S local	S
Rusty blackbird	M	W		W
C. grackle	S	P		P
Starling	P	P		P
N. oriole	S	S		S
Common redpoll	W	W	W	W
Hoary redpoll	W	W	W	W
Purple finch	S/P	W		W
Am. goldfinch	S	P		P
Rose-breasted grosbeak	S	S	S	S
Indigo bunting	S	S	S	S
White-throated sparrow	S	M	M	W
White-crowned sparrow	M	M		M
+ Swamp sparrow	S	S	S	P
+ Song sparrow	S	P	S	P
+ Lincoln's sparrow	S	M		M
Savannah sparrow	S	S	S	S
Henslow's sparrow		S		S
Sharp-tailed sparrow	S			
+ LeConte's sparrow	S	M		M

(Table 1 continued next page)

(Table 1 continued)

Mammals	North	South	Prairie	Lower Michigan
Opossum		X		X
Masked shrew		X	X	X
Arctic shrew	X			
+ N. water shrew	X			
Pygmy shrew	X	X	X	
Least shrew		X		
Shortail shrew	X	X	X	X
BATS-Aerial and/or tree roosters				
Little brown myotis	X	X	X	X
Keen myotis	X	X	X	X
Indiana		X		X
Silver-haired bat	X	X	X	X
E. pipistrel		X		
Big brown bat	X	X	X	X
Red bat	X	X	X	X
Hoary bat	X	X	X	X
Black bear	X			
Raccoon	X	X	X	X
Fisher	X			
Short-tailed weasel	X	X	X	
Long-tailed weasel	X	X	X	
Least weasel	X	X	X	X
+ Mink	X	X	X	X
+ River otter	X	X	X	X
Spotted skunk		X	X	
Striped skunk	X	X	X	X
Red fox	X	X	X	X
Gray fox	X	X	X	X
Coyote	X	X	X	X
Gray wolf	X			
Lynx	X			
Bobcat	X			
Franklin's gr. squirrel		X	X	
+ Beaver	X	X	X	X
Deer mouse	X	X	X	X
White-footed mouse		X	X	X
S. bog lemming	X	X	X	X
Boreal redback vole	X			
Meadow vole	X	X	X	X
+ Muskrat	X	X	X	X

(Table 1 continued next page)

(Table 1 continued)

Mammals	North	South	Prairie	Lower Michigan
Meadow jumping mouse	X	X	X	X
Woodland mouse	X			
Snowshoe hare	X			
Cottontail		X	X	X
White-tailed deer	X	X	X	X
+ Moose	X			

Herpts	North	South	Prairie	Lower Michigan
TURTLES				
+ Snapping turtle	X	X	X	X
Wood turtle	X			
+ Spotted t.				
+ Stinkpot		X		X
+ False map t.		X		
+ W. painted t.	X	X	X	
+ Midland painted t.				X
+ Blandings turtle		X		X
SNAKES				
N. red-bellied snake	X	X	X	X
+ Texas brown s.		X		
+ Midland brown s.				X
+ Northern brown s.				X
+ N. water s.				X
+ Kirtland's water s.				X
+ Queen snake				X
+ W. Plains garter s.		X	X	
+ E. Plains garter s.		X		
+ Red-sided garter s.			X	
+ E. garter s.	X	X		
+ E. ribbon s.				X
+ W. ribbon s.		X		X
Blue racer		X		
W. smooth green s.		X	X	X
E. smooth green s.	X			
W. fox snake	(U.P.	X		X
E. fox snake				
+ Black rat snake				X
+ E. massasauga		X		X
				X
+ **SALAMANDERS**				
Mudpuppy	X	X	X	X
Blue-spotted sal.	X	X		
Jefferson sal.		X		X
Spotted sal.		X		X
E. tiger sal.		X		
Cent. newt	X	X		X
Red-spotted newt				X
Four-toed sal.	X	X		X

(Table 1 continued next page)

(Table 1 continued)

Herpts	North	South	Prairie	Lower Michigan
+ **TOADS & FROGS**				
Great Plains toad			X	
American toad	X	X	X	X
Dakota toad			X	
Blanchard's cricket frog		X		X
N. spring peeper	X	X		X
E. gray treefrog	X	X	X	X
Boreal chorus frog	X		X	
W. chorus frog		X		X
Bullfrog	(Wis&E U.P.)			X
Mink frog	X			
Green frog	X	X		X
N. leopard frog	X	X	X	X
Pickerel frog		(Wis.&E U.P.)		X
Wood frog	X	X		X

+ = Wetlands
S = Summer
W = Winter
P = Permanent
M = Migrant

Impoundments are especially beneficial to water birds. After the flooding of a freshwater impoundment in Ontario, Boyer and Devitt (1961) noted a "substantial increase in species of water birds already common to the region and an extension of ranges of others." He also demonstrated its importance as a duck production center and as a resting place for migrating waterfowl.

Mammals

Of 67 mammalian species in the Lake States, 6 could be classified as having wetland habitats (mink, river otter, muskrat, beaver, northern watershrew, and moose) and about 40 others as being associated with or attracted to wetland edges. We recorded 38 mammals associated with impoundments in the Chippewa.

Herpts

Thirty-four reptile and 22 amphibian species occur in the Lake States. Of these 56 species, 28 prefer wetland habitats and another 12 can be found in edge habitats or in wet areas for breeding only. In the table, subspecies of some herpts are listed due to distinctive range or habitat characteristics. Lower Michigan has 10 species or subspecies not found in the other Lake States region.

A total of 412 vertebrate species may be found in the region, of which 264 can be associated with wetlands or wetland edges. The vertebrate list for the wetlands of the Chippewa National Forest, based on our study (Probst *et al.* 1983) plus those of Mathisen *et al.* (1974) and Kirby (1975), was 157 birds, 44 mammals and 14 reptiles and amphibians for a total of 215 out of 308 species listed on the Chippewa National Forest.

HABITAT FACTORS

Water

Water provides a source of food, cover, and drinking water for a variety of wildlife. In his study of beaver flowages, Kirby (1975) estimated that 4 mammals, 22 birds, and 6 herpts, would not have been present without the occurrence of open water.

According to Karr (1968), the addition of open water areas results in an increase in the heterogeneity of the habitat with a corresponding rise in the distribution and abundance of birds. Reese and Hair (1976) also noted an increase in avian use by species not normally associated with wetland habitat, on an area recently flooded by a beaver dam.

The principal birds of open water in the region are waterflowl, with 22 species of ducks, swans and geese; 5 grebes; loon and coot. Piscivorous birds such as king-

fishers, cormorants, terns, and herons are also benefited. Loons and diving ducks need expanses of open water for takeoff. Another group of birds uses the open space over water for aerial foraging, either hawking after insects or sighting prey in or around the water. These include nighthawks, swallows, terns, ospreys, and bald eagles. Common snipe often perform their aerial courtship displays over open water.

Bats also utilize the aerial space over the impoundments, especially in forested areas. Other mammalian species such as the muskrat, river otter, and beaver are totally dependent on the aquatic habitat. Mink, reacoon, and moose rely heavily on water areas for food resources.

The presence of water is critical to many reptiles of the Lake States and to all amphibians for some part of their life cycles. All amphibians breed in water and spend either their larval or adult form in aquatic environments. Many snakes use aquatic edges for the abundance of prey found there, and most turtles in the Lake States are aquatic.

Food

Open water provides a direct source of food for many wildlife species, in the form of aquatic vegetation, invertebrates, and fish. With their high net productivity, water impoundments support the entire aquatic food chain. This is especially true in the younger vegetative stages which can be maintained in impoundments through water level manipulation (Probst *et al.* 1983, Harris and Marshall 1963, Kadlec 1962).

Plant Food

Primary production in impoundments is heavily based on aquatic plants. They provide either a direct or indirect source of food for herbivores or primary consumers. As a direct source they produce seeds--an important food source for many birds and small mammals--in greater quantities than other habitats. In a study of wetlands in southeastern Wisconsin, Wheeler and March (1979) found seeds to be very numerous in bottom samples from all types of wetlands and stressed their "important role in wetland use and potential waterfowl value". Seed production by aquatic vegetation is stimulated by slowly declining water levels (Keith 1961) which can be part of an impoundment management plan. Some important seed-producing plants include pondweeds (*Potamogeton* spp.), smartweeds (*Polygonum* spp.), wild rice (*Zizania aquatica*), arrowheads (*Sagittaria* spp.), spikerushes (*Eleocharis* spp.), bulrushes (*Scirpus* spp.) and sedges (*Carex* spp.). Evans and Kerbs (1977) call the widespread sago pondweed (*Pontamogeton pectinatus*) the "most important single waterfowl food plant". A species like wild rice not only provides a good food source but also good cover.

Although seeds are important for many ducks and other birds, vegetative plant parts also provide food. Wigeons and gadwalls make less use of seeds and fruits (Keith 1961) and feed more upon the leaves and stems of aquatic plants. Canvasbacks and other divers also feed on vegetative parts as do some turtles, beaver, muskrat, white-tailed deer, and moose. Minnows and tadpoles eat algae and other vegetation.

Animal Food

Aquatic vegetation provides an indirect food source by serving as a "culture medium" (Stoudt 1944) for invertebrates, which are especially important for waterfowl broods. Moyle (1961) relates the production of invertebrates both to the type and volume of aquatic vegetation present. Plants with finely dissected leaves or many branched stems are usually most productive as a base for invertebrates. For example, coontail (*Ceratophyllum demersum*) is not a good direct food source but harbors quantities of aquatic insects (Evans and Kerbs 1977). Duckweed (*Lemna* spp.) and Bladderwort (*Utricularia* spp.) also support large quantities of invertebrates. Whitman (1976) states that duckweed harbors "significantly larger numbers of invertebrate taxa than any other" aquatic plant. Invertebrate populations are greater in new impoundments and much reduced in older impoundments that are not managed (Kaminski and Prince 1981). Some abundant and widespread plants like cattail provide good cover but are relatively poor for producing invertebrates.

Many researchers have noted the reliance of waterfowl on animal foods during egg-laying periods. Wheeler and March (1979) give figures of 58.7 percent animal food for pre-laying blue-winged teal hens and 92.8 percent for laying hens. Ducklings also consume significant quantities of invertebrates. Bird species can differ as to which insect life stages they utilize. Although duck broods consume aquatic and larval forms, swallows and other aerial foragers eat the adult flying forms.

Food Chain

Carnivores and herbivores are attracted to this highly productive food chain provided by aquatic vegetation and invertebrates. Impoundment herbivores include muskrat and beaver, both of which feed on emergent and aquatic vegetation. Deer and moose are attracted to these areas to feed on the aquatics and wetland shrubs. Small mammals make use of the abundant seed production along impoundment edges. Invertebrates are food sources for snakes, turtles,

frogs, shorebirds, rails, some waterfowl, and wetland passerines such as marsh wrens and blackbirds. Amphibians, snakes, and the larger invertebrates are in turn consumed by herons, egrets, raccoons, and mustelids. Many wildlife species are attracted to impoundment edges for food and water. Skunks and raccoons are particularly fond of these areas and also pose a serious threat to waterfowl nesting. The interspersion of edges created by new impoundments is also beneficial to black bears, fox, fisher, and bobcats. As noted above, many waterfowl species depend on the vegetation as do some turtles, tadpoles, minnows, and fish such as bullheads and carp. The fish in turn provide an abundant supply of food for piscivores. Mergansers, loons, cormorants, kingfishers, terns, ospreys, bald eagles, and herons all benefit from this resource. Among mammals, otter and mink prey not only on fish but also on crustaceans and amphibians.

Food Availability

Although newly flooded impoundments possess abundant plant and invertebrate food resources, they often are not readily available to the feeding animal. Water levels influence both the type of vegetation that is present in an impoundment of its availability. When impoundments are too deep, dabbling ducks have difficulty reaching the bottom. For example, as the water depth increased, Wheeler and March (1979) noted that diets of dabbling ducks shifted from seeds to invertebrates. He also observed that mallards and blue-winged teal utilized seeds and insects in proportion to their abundance and availability. Low water levels benefit shorebirds by exposing mudflats for foraging and are attractive to waders by concentrating prey species in shallow pools. Dense stands of emergents may have abundant invertebrates, but access and movement are restricted. A dense edge of shrubs will also restrict wildlife access.

It's obvious there will be regional and seasonal differences in the abundance and availability of various food sources. Insects emerge at different times over the spring and summer months. There also may be conflicting habitat requirements among species. For example, a dense edge of willows will provide good forage for deer and moose but it also impedes access to the impoundment for other wildlife. Cattails provide food and shelter for muskrats but dense stands limit use by waterfowl.

Fluctuating Water Levels

As mentioned previously, several studies have shown that during the first year after flooding there is an increase in the density and diversity of wildlife followed by a decline after a few years. But fluctuating water levels can benefit wildlife by retarding hydric succession and maintaining vegetation in younger stages of higher net productivity. The final links in the food chain, the decomposers, are aided by drawdowns in impoundments which expose the organic material on the bottoms. As Kadlec (1962) and other researchers have noted, many productive waterfowl areas are drawn down naturally during droughts. This is successfully imitated in artificial water impoundments where the level can be manipulated.

In direct response to vegetation change, invertebrate food sources also react favorably to fluctuating water levels. Another important aspect of fluctuating water levels is the exposure of mudflats which attract shorebirds. Other drawdown effects are covered in more detail elsewhere in the workshop proceedings.

Habitat Complexity

The increase in interspersion due to water level fluctuation results in an increase in habitat complexity. MacArthur (1964) and Rothe (1976) have related increases in avian diversity to patchiness of habitat. Other studies (MacArthur and MacArthur 1961, Willson 1974, Probst 1979) have linked avian diversity to the vertical complexity of foliage. Karr's (1968) research suggests the addition of open water adds a major structural factor to the habitat which leads to an increase in the abundance and diversity of wildlife. In a study on beaver flowages, Reese and Hair (1976) found that open water increased the potential for production of food sources which in turn attracted non-wetland species. Bird, mammal, reptile, and amphibian species are attracted to the interspersed impoundment habitat.

The initial flooding and subsequent water level manipulation in an impoundment increase the amount of edge and the degree of interspersion of habitat types. This interspersion of open water, emergents, shrubs, upland openings, and timber results in greater numbers and kinds of wildlife. Leopold (1933) relates edge to animal numbers. Diversity and density of species is a function of the number of kinds of edge and density is also a function of the total length of edge. Weller and Frederickson (1973) found the peak of avian production to occur when the emergent plant to water ratio was about 50:50. Kaminski and Prince (1981) found the same ratio to be optimum for dabbling duck breeding pair densities and species density. In studies of a flooded timber area, Cowardin (1969) found the highest waterfowl use near edges where dead timber was interspersed with emergents, and Harris (1957) found that interspersion increased nesting opportunities for ducks.

SUGGESTIONS FOR HABITAT MANAGEMENT

Once the need for an impoundment is established, the land manager should select a site that maximizes the interspersion of habitat types after flooding for the greatest diversity of wildlife species. These types should include open water, emergent vegetation, wetland shrubs, flooded dead timber, and adjacent edges of upland openings, shrubs, and live timber. Depending on the location, some of these types may not be present or the goal may be to manage for a single species or group of species, such as the osprey, muskrat, or dabbling ducks. Most management to date has been for game and some furbearing species. Tradeoffs may have to be made when deciding management objectives.

Open Water

As noted before, open water areas add greatly to the habitat heterogeneity and diversity of wildlife. Impoundments with expanses of open water are attractive to osprey, kingfishers, terns, muskrats, beaver, and most waterfowl, especially common loons, ring-necked ducks, common goldeneyes, and mergansers. Open water areas with submerged and floating-leaved vegetation provide food for beaver, moose, and other animals. From our study (Probst *et al.* 1983) 2 ha of open water appears to be minimum for attracting waterfowl to this habitat. Most waterfowl prefer small areas for raising broods. Impoundments usually provide this. Depths less than 18 inches are ideal for dabbling ducks (Linde 1969). Larger open water expanses are needed for the flightless period (Gilmer 1977), thus impoundments located adjacent to larger bodies of water should be more attractive to waterfowl. The same could hold true for the migration periods. In the smaller, shallower impoundments the surface water warms faster and provides food for early migrants (Swanson *et al.* 1974.

Vegetation replaces open water areas when water levels are not managed. Bogs of the northern Lake States are prime examples of this problem.

Emergents

Dense stands of emergent vegetation provide thick cover, an abundant invertebrate food supply and poor-to-good vegetative food supplies. Birds such as the least and American bitterns, sora and Virginia rails, long-billed marsh wren, and yellow-headed blackbirds utilize these areas exclusively. While some waterfowl like the redhead and ruddy duck use them for nesting. But only when they are interspersed with a variety of other habitat types do they provide the optimum benefit for the greatest diversity of wildlife.

Emergent cover is vital for waterfowl broods, but if too dense, it impedes movement. Interspersion with patches of open water provides access to the abundant insects and facilitates escape from predators. Once emergent stands are opened up, other wildlife is attracted. Terns, ducks, grebes, coots, and gallinules will build nests on mats of dead vegetation and forage in these openings. Muskrats will create openings and their houses provide nesting and loafing platforms.

Monotypic stands of emergents, especially cattails, are detrimental. Cattails provide good cover but low food quality for most wildlife species except muskrats. In contrast to cattails, bulrushes and wild rice provide both excellent food and cover.

White-tailed deer often feed on emergents in shallow waters. Other wildlife not associated with wetlands utilize emergent vegetation in winter months. Pheasants, prairie chickens, and cottontail rabbits may use these areas for winter cover, especially in the agricultural and prairie regions where suitable habitat is scarce. On a SE Wisconsin study area, two-thirds of all successful pheasant clutches were located in wetland cover (Gates 1970).

Wetland Shrubs

Flooded shrubs provide nesting and resting cover for a number of wildlife species but will die if flooding is too deep. Willows or alders can quickly invade the shoreline after a drawdown and in 3 to 5 years will close in the edge (Harris 1957) if there are no subsequent controls. Shrubs can supply browse for deer and moose at this stage but are generally detrimental. Once again, interspersion with other types is more beneficial. When interspersed with emergents, shrubs are especially good for dabbling ducks and broods. Wood ducks are commonly found in them and shrub swamps are favored nesting areas of black ducks.

Smaller passerine birds like the eastern kingbird and alder flycatcher may also nest in wetland shrubs. They also forage from them as do the swamp sparrow, song sparrow, common yellowthroat, red-winged blackbird, and yellow warbler. Migrant warblers make much use of wetland shrubs, especially in spring. Ruffed grouse may use alder swamps for brood cover and feeding (Golet 1972). Along with deer and moose, beaver use them as food. In non-forested regions, wetland shrubs provide valuable winter cover for pheasants, cottontails, (Golet 1972) and other wildlife. In northern regions snowshow hare will use shrub swamps as winter cover.

Flooded Dead Timber

Another major habitat component of impoundments is flooded dead timber. It is attractive to cavity nesters such as wood ducks, goldeneyes, mergansers, and tree swallows, and may be used by colonial nesting herons, cormorants, and osprey. The timber provides foraging perches for kingfishers, raptors, shrikes, and flycatchers and a foraging substrate for woodpeckers and nuthatches. Kadlec (1962) noted that flooded areas of dense timber can provide a refuge for waterfowl in the hunting season.

Dense stands with numerous fallen trees provide roosting and loafing sites for many waterfowl, turtles, and other wildlife. These stands reduce wind and wave action. As a result, dense masses of duckweed often form, which in turn provide an ample food source. When drawn down, flooded timber areas are rapidly invaded by emergents and the resulting mix of vegetation leads to greater wildlife use (Cowardin 1969).

Our study (Probst *et al.* 1983) found 35 bird species in flooded timber areas, 6 of which were not recorded outside this habitat type, including the green heron, red-headed woodpecker, tree swallow, and shrikes.

Nesting Structures

Providing nest structures (nest boxes, platforms, or islands) can be part of impoundment management plans. Nest boxes can be put up for wood ducks, goldeneyes, and mergansers but may also be utilized for nesting or cover by screech owls, kestrels, tree swallows, starlings, flickers, flying squirrels, raccoons, deer mice, and others. The placement of boxes is important because they can be more vulnerable to predation than natural cavities (Bellrose *et al.* 1964). In one impoundment, we observed a mink systematically entering boxes placed over water on poles. Conical shields placed around the poles could have prevented this predation. Other animals that cause problems include raccoons, fox squirrels, starlings, and some snakes. According to Bellrose (1976) risk of predation is increased when unshielded boxes are grouped closer than 1 per 10 acres. If boxes are shielded, groups of 2-4 per acre have the highest use.

Platforms are useful to some wildlife, especially Canada geese (Rienecker 1971). Nest baskets have been used by the adaptable mallard. Osprey and cormorants may use suitably located platforms. Meier (1981) reported greater production for cormorants on artificial platforms than natural nest sites. Great blue herons also used the platforms.

Islands, natural or man-made, are favored nesting and loafing spots for waterfowl and are used by other birds and turtles. According to Giroux (1981) artificial islands may cost more than nest boxes or platforms but they require less maintenance. Also, more ducklings and goslings are hatched per unit areas on islands and they are used by a greater diversity of species.

Loons and ring-necked ducks prefer islands for nesting and Canada geese, mallards, and other waterfowl also use them when available. In large impoundments, islands could possibly be used by colonial nesters such as the common tern or white pelican. McIntyre and Mathisen (1977) reported that artificial islands were used as readily as natural islands for nest sites by common loons. Sedge mats 40-60 cm thick and 1-6 m^2, were cut with a hay saw and anchored in open water 1-2 m deep and 3 to several hundred m from the shore. Ring-necked ducks especially favor the sedge-mat islands. Linde (1969) describes another method of island construction for areas without sedge mats. In winter, either brushpiles covered with hay or piles of earth are placed on top of the ice. These are particularly good for Canada geese and mallards, but last only 1-4 years depending on the weather. Another technique is to bulldoze a "push-up" of earth after a drawdown. To reduce erosion of islands, managers should consider distance from shore, water depth, and placement.

Other artificial structures for impoundments include placing loafing logs for ducks and turtles and erecting perches for osprey and other raptors or piscivores.

Drawdowns

Water level manipulation techniques are covered more thoroughly elsewhere in this workshop proceedings. In general, drawdowns permit the release of nutrients trapped in bottom soils, prevent drowning of shrubs, and stimulate the growth of emergents. All this increases interspersion of cover and water, increases food, and results in a greater abundance and diversity of wildlife species.

More research is needed on the timing and duration of drawdowns, and whether they should be partial or complete. These considerations impact groups of wildlife differently. The habitat and food requirements of wildlife are diverse so land managers must define their wildlife objectives. Waterfowl habitat is a primary concern in many areas, but managers can also enhance other wildlife in conjunction with waterfowl or as an alternative goal.

A gradual drawdown that continually exposes new mudflats is very beneficial to shorebirds (Rundle and Fredrickson 1981). These mudflats are especially important in northern forested areas and during peak shorebird migration in August. Fewer duck broods were noticed by Keith (1961) where mud shorelines existed, thus any drawdown during the brood season

may be detrimental. Subsequent reflooding after shorebird passage could benefit migrating waterfowl and retain more for the hunting season.

Drawdowns can be used to remove pest species such as carp, snapping turtles, and muskrats if they are adversely affecting vegetation and waterfowl. Also during drawdowns, islands can be constructed and the basin seeded for waterfowl food or cleared of debris if necessary. Wading birds are attracted to drawdowns where amphibians and fish are forced into shallower pools of water. The same holds true for raccoons and other carnivores. Overwinter drawdowns could control muskrats or carp but at the same time would reduce the number of amphibians and turtles that burrow into the bottom mud. Invertebrate populations may be adversely affected by drawdowns, depending on their extent and duration (Linde 1969, Swanson 1977).

Create Openings

Managers can create openings in the impoundment proper by manipulating water levels. Upland clearings around the impoundments edge should also be considered for wildlife nesting, food, and cover needs. Dams or dikes built to impound water furnish suitable habitat for some species such as killdeer, spotted sandpipers, meadow voles, jumping mice, and ground squirrels. Waterfowl may use them for loafing sites but nests located there would be too vulnerable to predation. The smaller the area of upland nesting the greater the vulnerability to predation (Moyle 1964). Low and tall grasses mixed with herbs would be beneficial. Some dabbling ducks will nest up to 500 yards from water (Moyle 1961). Pheasants will use nesting cover around impoundments in agricultural areas (Gates 1970). Greater wildlife diversity is achieved if there is a mixture of forest and upland openings around the impoundment.

Fish Management and Crop Planting

Fish management and crop planting are additional management techniques to consider. Minnows are important links in the food chain and should be considered when planning drawdowns. Managing for fisheries will be covered in another workshop paper.

Wildlife food crops can be planted to attract and hold waterfowl populations during the fall migration. Upland crop planting can provide food and cover for other wildlife as well. Mudflats can be exposed with summer drawdowns, seeded, and reflooded in fall (Harris 1957). In SE Wisconsin, Linde (1969) found buckwheat and Japanese millet can be artificially seeded with success. Wild rice proved to be the most successful crop in Emerson's (1961) study. Impoundment basins can also be tilled for planting during drawdowns.

SUMMARY

Table 2 summarizes the benefits described in the main text. It covers habitat needs and management strategies for certain species or groups of species.

Land managers should first define their wildlife goals. Endangered, threatened, or sensitive species may warrant special consideration. This would still benefit many other species but the optimum benefit for the greatest number and diversity of species will result from the maximum interspersion of open water, emergents, wetland shrubs, and flooded timber. Reptile and amphibian numbers are generally increased by practices that benefit other wildlife, but complete drawdowns could have a drastic effect on local populations.

In addition to the traditional values held for waterfowl and other game species, many nongame species are esthetically valued by nonconsumptive users. Impoundments can attract wildlife and provide hunters, trappers, fishermen, birders, nature photographers, and nature study groups with recreation.

LITERATURE CITED

Bellrose, F. C.; Johnson, K. L.; Meyers, T. U. Relative value of natural cavities and nesting houses for wood ducks. J. Wildl. Manage. 28: 661-676; 1964.

Bellrose, Frank C. Ducks, geese and swans of North America. 2d ed. Harrisburg, PA: Stackpole Books; 1976. 540 p.

Beule, J. D. Control and management of cattails in SE Wisconsin wetlands. Tech. Bull. 112. Madison, WI: Department of Natural Resources; 1979. 40 p.

Boyer, G. F.; Devitt, O. E. A significant increase in the birds of Luther Marsh, Ontario, following freshwater impoundment. Can. Field Nat. 75(4): 225-237; 1961.

Cowardin, L. M. Use of flooded timber by waterfowl at the Montezuma National Wildlife Refuge. J. Wildl. Manage. 33(4): 829-842; 1969.

Crider, J. E. A wildlife inventory of the Sturgeon River Wilderness study area. Michigan Technical University; 1979. 67 p. M.S. thesis.

Emerson, F. B. Experimental establishment of food and cover plants in marshes created for wildlife in NY state. New York Fish and Game J. 8(2): 130-144; 1961.

Evans, K. E.; Kerbs, R. R. Avian use of livestock watering ponds in W. South Dakota. Gen. Tech. Rep. RM-35. Fort Collins, CO: U.S. Department of

Table 2.-- *Habitat improvement for vertebrate species and species groups*

Habitat improvement	Waterfowl	Shorebirds	Waders & waterbirds	Piscivores	Raptors	Insectivores	Others
Open water	loon mergansers ring-necked d. mallard	phalarope	herons egrets cormorants coots	kingfisher gulls terns	osprey bald eagle		otter muskrat beaver turtles
Emergents	b.w. teal redhead ruddy duck grebes		sora Virginia rail bitterns c. gallinule	terns (nests)	harrier	marsh wrens blackbirds swamp sparrow	muskrats pheasants (Wntr cover) beaver
Wetland shrubs	wood duck black duck		green heron			e. kingbird alder flycatcher c. yellowthroat yellow warbler song sparrow	beaver moose deer
Flooded dead timber			green heron great blue h. cormorant	kingfisher	osprey b. eagle kestrel	tree swallow flycatchers starlings woodpeckers	bats
Mudflats		spot, sandpi. killdeer yellowlegs snipe	herons			grackles	raccoon mink
Upland openings	nesting ducks	nesting sp. killdeer spot, sandpip.	sandhill crane		harrier s.e. owl	sparrows flicker	gr. squir. fox
Forest edge mgmt	wood ducks				red-sh. hawk owls	forest passerines	squirrels tree frogs
Crops	geese	godwits (cover)	sandhill crane		harrier	red-winged blackbird	pheasants
Perches			cormorants	kingfisher	osprey eagle		
Boxes	wood duck c. goldeneye mergansers				kestrel	tree swallow flicker crested flyc. screech owl	raccoon squirrels snakes
Platforms	geese		cormorants		osprey		
Sedge islands	loon ring-necked d. grebes		rails bitterns	terns			

Agriculture, Forest Service, Rocky Mountain Forest Range Experiment Station; 1977. 11 p.

Gates, J. M. Recommendations for a scattered wetlands program of pheasant habitat preservation in SE Wisconsin, Res. Rep. 63. Madison, WI: Department of Natural Resources; 1970. 24 p.

Gilmer, D. S. Post-breeding activities of mallards and wood ducks in north central Minnesota. J. Wildl. Manage. 41(3): 345-359; 1977.

Giroux, J. F. Use of artificial islands by nesting waterfowl in SE Alberta J. Wildl. Manage. 45(3): 669-679; 1981.

Golet, F. C. Classification and evaluation of freshwater wetlands as wildlife habitat in the glaciated northeast. University of Massachusetts; 1972. Dissertation.

Harris, S. W. Ecological effects of drawdown operations for the purpose of improving waterfowl habitat. Minneapolis, MN: University of Minnesota; 1957. 205 p.

Harris, S. W.; Marshall, W. H. Ecology of water-level manipulations on a northern marsh. Ecology 44(2): 331-343; 1963.

Kadlec, J. A. The effects of a drawdown on a waterfowl impoundment. Ecology 43: 267-231; 1962.

Kaminski, R. M.; Prince, H. H. Dabbling duck and aquatic macro-invertebrate responses to manipulated wetland habitat. J. Wildl. Manage. 45(1): 1-15; 1981.

Karr, J. R. Habitat and avian diversity on stripmined land in east-central Illinois. Condor 70: 348-357; 1968.

Keith, L. B. A study of waterfowl ecology on small impoundments in SE Alberta. Wildl. Monogr. 6; 1961. 88 p.

Kirby, R. E. Wildlife utilization of beaver flowages on the Chippewa National Forest, North Central Minnesota. Loon 47(4): 181-185; 1975.

Linde, A. F. Techniques for wetland management. Res. Rep. 45. Madison, WI: Wisconsin Department of Natural Resources; 1969. 156 p.

Leopold, A. Game management. NY: C. Scribner's Sons; 1933. 481 p.

MacArthur, R. H. Environmental factors affecting bird species diversity. Am. Nat. 98: 387-397; 1964.

MacArthur, R. H.; MacArthur, J. W. On bird species diversity. Ecology 42: 594-598; 1961.

Mathisen, J. E.; Harper, J.; Dittrich J.; McIntyre, J. Evaluation of wetland development. Cass Lake, MN: Chippewa National Forest. 1974. 36 p. Unpubl. rep.

McIntyre, J. W.; Mathisen, J. E. Artificial islands as nest sites for common loons. J. Wildl. Manage. 41(2): 317-319; 1977.

Meier, T. I. Artificial nesting structures for the double-crested cormorant. Tech. Bull. 126. Madison, WI: Department of Natural Resources; 1981. 12 p.

Moyle, J. B. Aquatic invertebrates as related to larger water plants and waterfowl. Investigative Rep. 233. Minnesota Department of Conservation; 1961. 24 p.

Probst, J. R. Oak forest bird communities. In: Proceedings, The management of north central and northeastern forests for nongame birds; 1979 January 23-25; Minneapolis, MN. Gen. Tech. Rep. NC-51. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1979: 80-88.

Probst, J. R.; Rakstad, Don; Brosdahl, Kathy. Diversity of vertebrates in wildlife water-impoundments on the Chippewa National Forest. Res. Pap. NC-235. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1983. 22 p.

Reese, K. P.; Hair, J. D. Avian species diversity in relation to beaver pond habitats in the Piedmont Region of South Carolina. SE Assoc. of Game and Fish. 437-447; 1976.

Rienecker, W. C. Canada goose nest platforms. Calif. Fish and Game 57: 113-123; 1971.

Roth, R. R. Spatial heterogeneity and bird species diversity. Ecology 57: 773-782; 1976.

Stoudt, J. H. Food preferences of mallards on the Chippewa National Forest, Minnesota J. Wildl. Manage. 8(2): 100-112; 1944.

Swanson, G. A.; Meyer, M. I.; Serie, J. R. Feeding ecology of breeding blue-winged teal. J. Wildl. Manage. 38: 396-407; 1974.

Weller, M. W.; Fredrickson, L. H. Avian ecology of a managed glacial marsh. Living Bird. 12th Annual. 269-291; 1973.

Wheeler, W. E.; March, J. R. Characteristics of scattered wetlands in relation to duck productivity in SE Wisconsin. Tech. Bull. 116. Madison, WI: Department of Natural Resources; 1979. 62 p.

Whitman, W. R. Impoundments for waterfowl. Occas. Pap. 22. Ottawa, ON: Canadian Wildlife Service; 1976. 22 p.

Willson, M. F. Avian community organization and habitat structure. Ecology 55: 1017-1029; 1974.

BEAVER IN WATER IMPOUNDMENTS: UNDERSTANDING A PROBLEM OF WATER-LEVEL MANAGEMENT

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The North American Beaver (*Castor canadensis* Kuhl, 1820) is one of two species belonging to the family Castoridae. It now occurs throughout North America except in peninsular Florida, deserts of the Southwest, and in the arctic tundra (Jenkins and Busher 1979). However, this distribution was broken in recent history. The quest for beaver pelts was a strong stimulus to exploration of this continent by Europeans. The result of this unregulated harvest was the extirpation of beaver throughout most of the contiguous United States by the early 1800's. There was a transition period during the late 1800's and early 1900's when numerous States prohibited the taking of beaver. The early 1900's was also a period during which numerous States began reintroducing and relocating beaver. In the Upper Midwest, this transition period also coincided with the pine logging era that subsequently resulted in abundant aspen forests favorable to beaver. In Minnesota the beaver had returned in sufficient numbers by 1940 to warrant the establishment of a regulated harvest (Longley and Moyle 1963).

The return of abundant beaver populations also brought problems, the same problems that we experience today (Peterson 1979, Woodward *et al.* 1976). They have a proclivity for building dams in ditches, along roadsides, in culverts, under small bridges, etc. Dams in these locations cause flooding, much to the dismay of highway departments, lake property owners, foresters and farmers. They frequently cut down ornamental or valued trees along lake or stream property. Lastly, and this addresses the subject of this symposium, they find artificial impoundments created for waterfowl to be quite suitable habitat. However, they instinctively respond to escaping water, whether from an impoundment full of water, or from one that is being rejuvenated through drainage. The result is plugged water control structures and conflicts with management plans. The intent of this paper is to explore these problems.

First I will lay a basis for understanding the problem by reviewing beaver natural history. I will selectively draw upon the literature and impressions I obtained from our beaver research. Next, I will reveiw what is known about their habitat requirements. Then, I will discuss the problems beaver cause in impoundments and why these problems occur. Finally, I will offer some potential solutions.

NATURAL HISTORY

Social Organization

The social organization of beaver is uncommon among mammals. They are monogamous, which means that they have a single mate who is usually retained for life. If their mate dies, they obtain a new mate from among the population of dispersing 2-year olds, unmated adults, or from among members of their family. Another trait of beaver that is uncommon in all but the larger mammals is their long parental care period. This period of development and association with their parents and other kin typically lasts 2 years.

The term "colony" is well entrenched in the literature on beaver. Actually this is a misnomer, for a beaver colony is more accurately a family of related individuals. The family can include a pair of adults and their offspring from the pervious 2 years. However, this "typical" family is only one of many possible combinations. Fur trapping, predation, and other causes of death distort family composition. Other factors such as habitat quality also affect family composition; thus reports of family composition vary greatly. Reports of the frequency of "typical" families (those with adults, yearlings, and kits) range from 19 percent (Bradt 1938) to 64 percent (Hodgdon 1978).

Family size and age class composition also vary with the above factors. The average family size for 22 studies listed by Hodgdon (1978) is 4.9 with a range of from 2.7 to 7.8. Conditions ranged from good to poor habitat and from exploited to unexploited populations. Hodgdon (1978) reported a population age class structure of 28 percent adults, 3 percent 2-year olds, 32 percent yearlings, and 37 percent kits, which is similar to reports of others (Payne 1982, Shelton 1966). How-

ever, age class structure varies widely. For example, the percentage of adults reported in 22 studies listed by Hodgdon (1978) ranges from 15 to 61 percent.

Reproduction

In northern regions, beaver breed once each winter from late January to early March with peak breeding in mid-February (Bergerud and Miller 1977, Hodgdon and Hunt 1966). Only the adult pair is reproductively active within the family unit. The gestation period is about 107 days (Wilsson 1971) and the young are born in May and June (Bergerud and Miller 1977, Hodgdon and Hunt 1966). Usually there are 3 to 4 kits in a litter although Novak (1972) reported that one female had 12 fetuses. The average litter size for 26 studies listed by Hodgdon (1978) was about 3.6. Litter size has been reported to vary with age, weight of female, quantity and quality of available food, and severity of winter (Boyce 1974, Henry and Bookhout 1969, Hodgdon and Hunt 1966, Pearson 1960, Rutherford 1964, and Yeager and Rutherford 1957).

Ontogeny and Dispersal

At birth, the kits weigh about 1 pound, are fully furred, their eyes are open, and their incisors have erupted. Within about 2 weeks (Wilsson 1971), they become interested in sampling herbaceous vegetation, principally the foliage of trees and shrubs brought into the lodge by the adults. Their milk diet is increasingly supplemented by vegetation brought into the lodge or cached on the lodge exterior. At the age of about 2 months, near the end of July or early August, they are weaned and appear increasingly outside the lodge to forage on their own nearby. By fall, they range almost as far from the lodge as older members of the family; however, they seldom venture on land or participate in a substantial way in lodge maintenance or constructing a winter food cache (Hodgdon 1978). By the time ice-up occurs, they usually weigh about 10 to 16 pounds.

During their second year with the family as yearlings, they participate more in construction, but not as much as adults do. They generally stay with the family until nearly two. They disperse as the ice leaves in the spring. Contrary to popular notion, there is considerable evidence that they are not driven off by the adults (Hodgdon 1978).

Dispersing beaver travel faster through occupied habitat than through unoccupied habitat (Hodgdon 1978). While traveling through the territories of resident beaver, they seldom stop. Residents show little interest in transients, even in one instance, when a transient passed within 3 m of a resident. After leaving an occupied territory, they reduce their rate of travel and resume normal activities.

Dispersal distances vary considerably. During dispersal, they move up to about 1.4 miles per day (Hodgdon 1978). Most dispersal is by water although they sometimes travel over land. Dispersing beaver have been known to travel up to 50 miles from the natal colony, but the average is closer to 5 to 6 miles (Hibbard 1958, Hodgdon and Hunt 1966, Hodgdon 1978). During the dispersal period, they attempt to locate a mate, either an unpaired adult, another unrelated 2-year old, or in some cases a sibling. If successful, they form a pair bond, mate the following winter, and produce their first litter at age 3.

Mortality

The cause and magnitude of mortality in beaver populations depends on local circumstances. Fur trapping, diseases, and predation can result in considerable mortality. In their absence, mortality is generally low, especially within the kit and yearling age classes (Hodgdon 1978). It is generally assumed that there is substantial mortality in the 2-year-old age class because of losses during dispersal.

Food Habits

The food habits of beaver suggest that they are "choosy generalists" (Jenkins and Busher 1979). That is, although they feed upon a wide variety of vegetation, they definitely prefer far fewer species. Beaver are best known for cutting and eating the bark of trees, but their diet is far more varied. Woody bark forms the bulk of their diet, especially during the leafless seasons. If preferred tree species are not readily available, they eat the bark of shrubs instead. However, even during this period, other food sources are used when available. For example, they may feed on aquatic plants that stay green all winter or on the root systems of aquatics such as the tubers of water lilies.

In the spring, the diet of beaver shifts from primarily woody bark to the developing herbaceous vegetation. At this time, they venture up to 10 m from shore to feed upon grasses, carex, and forbs, or the foliage of trees and shrubs adjacent to the water. As emergent and aquatic macrophyte vegetation develop, they are eaten. Thus herbs, foliage, emergents, and aquatics form the bulk of their diet during the summer months (Svendsen 1980b). If aspen is available near the shore, their summer diet may also include aspen bark and leaves. Toward fall, when the foliage of trees, shrubs, and herbaceous vegetation gets scarce, beavers turn again primarily to woody bark and aquatics.

Habitat quality is partly dependent on the availability of aspen and to a lesser extent aquatics. Shelton (1966) showed that beaver subsisting on aspen or aquatic macrophytes grew the best. Huey (1956) reported that litter sizes were larger for beaver subsisting on aspen than on willow or cottonwood. Thus aspen is preferred and beneficial to both their growth and productivity; the less there is the more beaver must seek out other food.

Territoriality

Beaver are territorial and communicate their presence within an area by constructing scent mounds. These are small mounds of mud, grass, and other debris located at the water's edge. They are placed most frequently at the perimeter of their territory and near activity centers. Beaver urinate on these mounds and in the process of urinating, castoreum from the castor glands is also deposited. Hodgdon (1978) reported that all family members older than 1 year participate in scent mounding, but adults are most active. While beaver are dispersing, they do not build scent mounds until they begin to settle in an area. At this time they actively create mounds, which advertises their presence in a territory.

Scent mounding behavior among residents is strongest in spring which corresponds with the dispersal period (Hodgdon 1978, Svendsen 1980a). Although scent mounds do not function as a "scent fence" (Svendsen 1980a), (transient beaver will pass through occupied territories), it does advertise the presence of residents to other beaver. Towards summer, this behavior and their interest in scent mounds wane. The exception to this penological pattern is when a family moves to a new site. During the initial period of establishment at the new site, scent mounding is intense, then wanes.

The home range of beaver varies considerably and partly depends on the characteristics of the body of water they are located upon. Lakes less than 80 to 100 acres in size with a low shore-to-area ratio usually contain only one family. On very large lakes, where wave action can be substantial, beaver lodges usually are found in sheltered bays, although their territories may include the nearby more exposed shorelines. On streams, their territories include not only the impounded water about the lodge, but also the stream sections above and below the dam perhaps extending as far as ¼ mile.

Beaver may change territories over the years depending on their quality. This is particularly true of territories that have marginal food resources. On lakes where food is scarce they use a different lodge each winter. On streams, they move to a different portion of the stream. In this manner they increase their efficiency and safety by not having to travel farther to obtain the food that they need from a declining resource base. This also results in a sort of rest-rotation of their food resources. In many cases, these moves are primarily a shift of activity centers within the same territory. However, they may continue to use the old lodges or impoundments, only less frequently. Where food is abundant, it is less likely that they will shift their activity center within the territory or move to a different location. In these situations, they may use the same lodge year after year.

Construction Behavior

There is a definite sequence and seasonality to their construction activities. If they are going to move, they usually do so either before the kits are born or more likely after the kits become somewhat independent. This means that they are likely to move in April to May or in August to September. Beaver without young are not restricted and therefore may more any time between April and September, but are more likely to establish themselves at new sites between June and August (Hodgdon 1978).

The sequence of construction activity depends on the availability of existing structures and the characteristics of the site. If a dam, a lodge, or both, already exists, they will generally use these structures after refurbishing them. Or, they may build other dams or lodges. If no structures exist, they begin by building a dam. During this period, they are usually either commuting from another lodge or living in a bank den that was recently constructed or already existed.

They begin the dam by placing branches at the chosen site and adding mud and other debris obtained from the bottom near the dam. Once the height of the dam is near the intended level (which usually creates a pond about 1.5 m deep), they begin construction of the lodge. A lodge may begin with several lodge starts, each start being a small pile of sticks on some prominence such as a mound of dirt, rock, or tree base somewhat above water level. They prefer lodge sites that are surrounded by water, but sometimes build along the edge of the impoundment, either within emergent vegetation or on the shore. Eventually, one lodge start is chosen, more sticks are added, a tunnel is constructed from below water, and a chamber is hollowed out under the pile of sticks. After a substantial pile of sticks accumulates, they add bottom mud to the lodge. Most mud is placed on the sides of the lodge with very little at the top. This results in a pathway for ventilation between the chamber and the outside air. This sequence of construction is important because the floor of the lodge is uniformly about 1 dm

above water, which doesn't leave much room for error. Because these construction behaviors are separated in time, there is less need for decision processes than would be required if they constructed both the dam and lodge simultaneously.

If one or several lodges already exist and they are not going to change location or construct a new lodge, they begin to maintain an existing lodge during late August or September. Again, they may start maintaining several lodges before one is eventually chosen as the lodge they will winter in. Maintenance consists of adding more sticks and mud to the lodge to increase its size and strength. This behavior is strong until early October (leaf-fall) when lodge maintenance tapers off and food pile construction begins. They begin the food pile by placing woody branches and other food items at or near the base of the lodge and continue adding until ice-up.

HABITAT REQUIREMENTS

Water

Beaver must have a reliable source of water. Intermittent streams or ponds are not suitable. Although beaver may attempt to colonize intermittent sources early in the season, they will abandon them later if they prove inadequate. Many beaver colonies are established in summer. One reason may be that the amount of water in spring is a poor predictor of the adequacy of water later in the season. Abnormally low river water in late summer or early fall can also create problems for beaver. When beaver attempt to construct dams under these conditions, the return of normal or above normal flows can destroy their efforts.

An estimate of the adequacy of water resources can be obtained by considering the normal precipitation pattern, the evaporation rate, soils, and the watershed area. With these inputs, a model can be constructed to determine the upper limits of a watershed where conditions are no longer suitable for beaver. The same inputs can also be used to define where flow rate and volume of water in rivers becomes too great. Alternatively, Verry (1985) has determined that the specific conductivity of water is a useful predictor of the reliability of water supplies.

Vegetation

The character of shoreline forest vegetation is a useful predictor of habitat suitability for beaver. Several studies have shown that the presence of hardwood vegetation on shorelines is positively correlated with the presence of beaver families. Slough and Sadlier (1977) reported that the length of shoreline in nonproductive brush and in particular aspen explained 90 percent of the variability in the number of colony sites on lakes. Similarly, the length of nonproductive brush or swamp stream shoreline explained 40 percent of the variability in the number of colony sites on streams. Thus food variables explained much of the variation on both lakes and streams.

Howard (1982) provided models in which the percentage of hardwood vegetation, watershed size, and stream width had positive effects, while increasing stream gradients and soil drainage had negative effects on the number of active colonies. These models were 75 to 80 percent reliable in classifying beaver habitat and 90 to 95 percent reliable in predicting the presence or absence of beaver. In addition, their food habits suggest that the presence of aspen, aquatic macrophytes, and emergent vegetation would enhance the probability of the occurrence of beaver, while the presence of only conifers would discourage them.

Physiography

Extremes in physiography can be detrimental. Stream gradients greater than 12 percent provide questionable beaver habitat. Retzer (1955) estimated that stream gradients in the range of 0 to 6 percent were best. Yeager and Rutherford's (1957) observations of dam breakage where stream gradients exceeded 6 percent and where the width of the valley was less than 150 feet, support this assertion. Also supportive is that others found few families where stream gradients were greater than 3 percent (Smith 1950, Hodgdon and Hunt 1966, Shelton 1966).

IMPOUNDMENT PROBLEMS

The preceeding information should suggest by this time that the habitat requirements of beaver are nearly guaranteed by creating waterfowl impoundments, except on streams flowing through closed-canopy conifer stands. However, the presence of beaver *per se* does not create problems in waterfowl impoundments. In fact they could be considered an asset. The problem lies with their innate repair behavior.

Under natural conditions, dam repair behavior is crucial to their survival. Thus it is not surprising that it is a strong, tenacious behavior. However, in the setting of an artificial impoundment, this behavior can raise havoc with water level management plans. Most water control structures are not adequately designed to prevent or reduce potential beaver problems. Thus, both at full pool and especially at drawdown, beaver are likely to create problems. In particular, they perceive the water flowing through the structure to be a "leak" that must be "repaired".

A beaver's perception of a "leak" is based on several stimuli. In particular, the sound of running water is a potent stimulus to the release of repair behavior (Wilsson 1971, Hartman 1975). In addition to audible stimuli, Richard (1967) believed tactile and movement stimuli elicited and directed repair behavior. It is also likely that the sight of escaping water is an operative stimulus. Thus any water level control structure that (1) produces a sound of running water, (2) produces the appearance of escaping water, (3) produces the feel of escaping water, and (4) is accessible to beaver, will elicit repair behavior.

Water Control Structure Designs

Designs of water control structures are varied. Only some have been designed taking beaver problems into consideration, as the following discussion shows.

Straight Culvert

Straight culverts are very prone to beaver problems, because water leaving the impoundment is visible, it creates the sound of running water, and it is accessible. The beaver's response is to plug the culvert with sticks, rocks, and mud. Thus this design is undesirable for controlling water levels at both full pool and at drawdown.

Spillway

A fixed spillway, with or without an apron, is prone to beaver problems for the same reasons as for culverts. The beaver's response is to build a dam across the spillway entrance. So without modification, this is also an unsatisfactory design at full pool. Because a culvert is typically used for drawdown, there are also problems during this stage.

Adjustable Overflow

In this design, the water level is controlled by placing boards (also called "stop-logs") in a channeled framework within the dam. In spite of the narrow edge where the water is flowing over the boards and the immediate drop off on the upstream side of the boards, this design is also prone to beaver problems for the same reasons as the above. Again, the beaver's response is to plug the overflow with sticks and mud at both full pool and at drawdown.

Drop-Tube or Riser

This is "L"-shaped and is typically constructed with culvert sections or concrete. It has a horizontal segment beneath the dam and a vertical segment attached at or near the intake end of the horizontal segment. The water drops down the vertical segment thus its height controls the water level. Beaver plug the overflow with sticks and mud and it is very difficult to clean out. It is prone to problems at both full pool and at drawdown.

Whistletube

This resembles a drop-tube or riser, only the vertical segment does not function as a drop-tube outlet, but contains channels in which boards or stop-logs are placed to regulate the water level. Thus water flows out from the bottom of the impoundment into the horizontal segment, then up one half of the vertical tube, over the highest board, and drops down the other half of the vertical tube to flow out. The vertical portion is positioned in the earthen dam to provide access for adjusting the level of the boards. This design is less prone to beaver problems, but beaver occasionally plug the intake end which then becomes difficult to clean out. At drawdown, when the horizontal portion becomes essentially a straight culvert, it is very prone to beaver problems.

Managing Beaver Problems

Approaches to managing beaver problems could be divided into three broad classes: population control, discouraging establishment, and regulating water levels in spite of beaver.

Population Control Methods

If control is desirable and regulations allow it, the following methods can be used to remove beaver. (These deal only with the current nuisance and do not address the potential for recurring problems).

Trapping.--In general, removing beaver with steel leg-hold traps using drowning sets, or with the Conibear 330[1] (Hill 1976, Hill and Gardner 1978), is the most practical way in the hands of competent trappers (Almand 1976, Hicks 1977, Jackson 1978, Miller 1977, Peterson 1979, Van Hoey n.d., Woodward *et al.* 1976). Using Hancock or Bailey live-traps for beaver is another alternative (Buech 1983, Taber and Cowan 1969), but these traps are more expensive.

Shooting.--This method is usually ineffective because of beavers' nocturnal habits, the time required to be in the right place at the right time, and because swimming beaver present a difficult target (Hicks 1977, Van Hoey n.d., Woodward *et al.* 1976). However, it can be effective in fall, when beaver are more active during twilight hours.

Miscellaneous.--Other methods have been used but are too specialized or not appropriate for various reasons. Although several poisons appear effective, none are approved for use (Hicks 1977, Hill 1976). Alligators may reduce--but probably do not eliminate--beaver populations (Arner *et al.* 1981, Hicks 1977). Trained dogs can be used to flush beaver from lodges

in drained ponds so they can be shot (Hicks 1977, Woodward *et al.* 1976). Several chemosterilants appear promising as antifertility agents (Gordon and Arner 1976), but the details of practical application have not been solved.

Discouraging Establishment

Techniques that have been tried for discouraging establishment or encouraging them to move out are many, but most are not effective.

Removal of dam, lodge, or both.--This procedure is probably the most used, but least effective method (Almand 1976, Guenther 1956, Hicks 1977, Miller 1977, Van Hoey n.d., Woodward *et al.* 1976). Typically, one or both are removed or partially destroyed either manually or with dynamite. The usual response is a repaired dam or lodge by the following day. Removal is most successful during the initial building period. Its effectiveness can be enhanced by complete removal of the dam and lodge, including removal of the building materials far enough from the site so they cannot be reused. however, even if you are successful, there is no assurance that another family will not try to settle later on.

Habitat alteration.--Land clearing to remove food resources has been tried with only limited success (Hicks 1977). If building material is scarce, complete removal of the remaining woody vegetation can be effective, *e.g.,* along ditches, canals, streams, ponds, and reservoirs in sparsely forested areas (Byford 1974, Miller 1977, Woodward *et al.* 1976). Alternatively, although it would take some time before it would be effective, the shorelines could be densely planted to conifers to shade out hardwood vegetation.

Repellants.--Various repellants have been tried to discourage repair behavior or feeding on valued trees. Huey (1956) reported 10 percent trinitrobenzene-aniline in acetone with arochlors to be the most effective for preventing damage to valued trees of four chemical repellants tested. Hicks (1977) reported that the deer repellant "Magic Circle" appeared promising. A new repellant, called "Ropel" (Atomergic Chemetals Corp., Plainview, NY), whose active ingredient is denatonium saccharide, has been advertised recently as an effective means of preventing beaver from cutting or feeding on vegetation. Other common chemicals have been tried with no success (Guenther 1956, Hicks 1977). Other repellants such as light and noise devices had little or no lasting effect on beaver repair activity (Guenther 1956, HIcks 1977, Van Hoey n.d.). I have tried wind-activated wolf silhouettes and wolf feces as deterrents to plugged culverts, also with no success. However, Guenther (1956) reported success using the scent of other natural predators (bear and cougar) carried on burlap bags from caged animals. When the bags were hung over the dam, beaver temporarily avoided the area, but resumed repair when the scent dissipated.

Johnson *et al.,* (1976) tried using electrically charged wires across dam breaks, but electrical deterrence of repair behavior was not effective because the system was too easily shorted out. However, others reported success with electric "shocker" fences (Woodward *et al.* 1976, Richard Joarnt personal communication). For example, Joarnt solved the shorting problem by attaching the noninsulated wire to a frame on floats (fig. 1). This device stopped beaver at all structures while the charger was operating. They still avoided the structures after the device was removed at three of four structures.

Two other repellant methods seem worth trying. One suggested by Peterson (1979) is to create and maintain artificial scent mounds at vacant problem sites to falsely advertise that the area is already occupied. Data provided by Muller-Schwarze and Heckman (1980) suggest this may be effective, but it could be costly to maintain. Another method I think is worth trying is to apply a substance with an extremely offensive odor, such as skunk oil to the dam break and lodge interior when beaver kits are not present. If offensive enough to beaver this could cause them to vacate the site. As with removal methods, it might be more effective if applied during the initial establishment phase.

Regulating Water Levels in Spite of Beaver's Presence

There are several alternative ways to meet your water level objectives in spite of the presence of beaver.

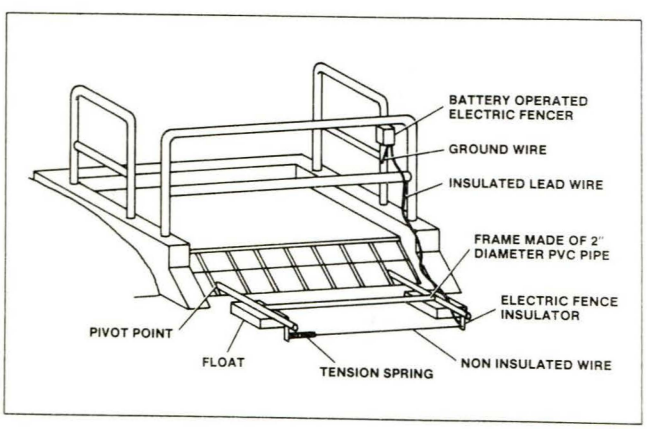

Figure 1.--*A device proposed by Joarnt (personal communication) to deter beaver nuisance behavior at water level control structures.*

[1]*Mention of trade names is for the convenience of the reader and does not constitute endorsement by the USDA Forest Service.*

Controlling the level in natural beaver ponds.--This can be accomplished by using drains of several designs. The objective in installing drains is to temporarily maintain the water at a tolerable level. Drains reduce sound and sight stimuli that trigger dam repair behavior, but they are not foolproof and may require occasional maintenance.

If scrap sheet metal is available, a "3-log" drain (fig. 2) can be effective and inexpensive (Bailey 1927). You can also use square wooden pipes with solid tops and sides and a slatted bottom, or perforated PVC pipe 16 to 24 feet long with a cap on the inlet end (fig. 3) (Almand 1976, Byford 1974, Hicks 1977, Huey 1956, Laramie 1963, Van Hoey n.d.). The drains are inserted in the dam so that one end is laid on the upstream side of the dam at the bottom of the pond and the other end extends beyond the dam on the downstream side. The outlet end of the pipe should extend far enough beyond the dam so the dam is not likely to be extended to cover it. The height of the outlet end determines the water level in the pond. Several drains may have to be installed depending on the volume of water passing through the pond.

Even so, drains don't always work. Guenther (1956) and Johnson *et al.* (1976) reported that beaver plugged the holes in perforated pipe, plugged the intake end on solid pipe, and in the case of a 3-log drain, they built a new dam above the drain. This suggests that

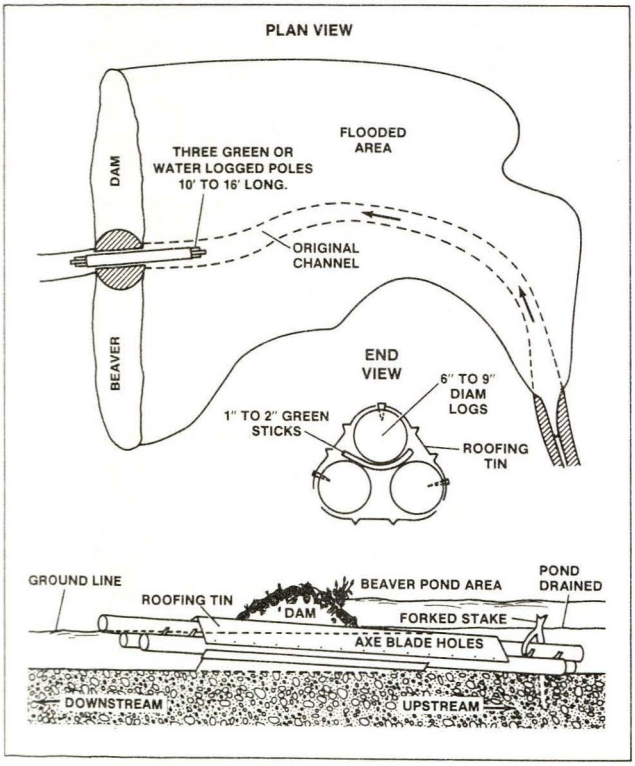

Figure 2.--*The "3-log drain" proposed by Bailey (1927) for regulating water levels in beaver ponds.*

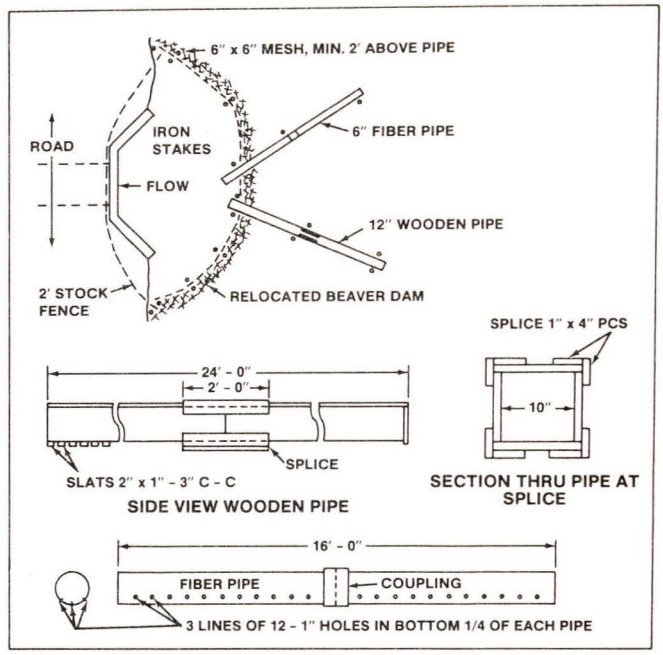

Figure 3.--*Slatted, wooden, and perforated PVC pipes proposed by Laramie (1963) for regulating water levels in beaver ponds.*

fencing or some other means of restricting access may be required to reduce tactile cues.

Guenther (1956) described a fencing arrangement that was successful for draining ponds at 16 installations over a period of 3 years. Called a "beaver baffler" (fig. 4), it consists of two parallel lines of woven wire fence about 3 feet apart extending from 15 to 20 feet below the dam, through the dam to a distance of 30 to 40 feet upstream in 1 to 3 feet of water. Woven wire cross sections are installed within the fenced lane in case beaver enter the lane from beneath the fence. Posts are placed close enough to hold the wire on the bottom.

Minimizing maintenance of existing water control structures.--Fences are particularly useful

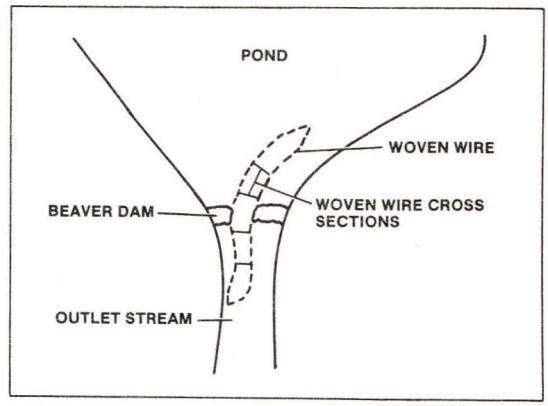

Figure 4.--*The "beaver baffler", a fencing arrangement proposed by Guenther 1956 for regulating water levels in beaver ponds.*

for reducing maintenance (Guenther 1956, Peterson 1979). Although fencing reduces the workload, it does not deter dam repair behavior; it redirects the behavior to where it is more easily handled. In this method, fencing is used to surround the intake end of culverts, spillways, adjustable overflows, or drop-tubes. Because the sound and sight of escaping water is still present, beaver respond by directing dam repair behavior as close as possible to the "leak". Because access is restricted, they attempt to repair the leak against the fence. Here, the material is easier to remove than say inside a culvert. Donald Potter (personal communication) reported he has successfully used sand bags in place of fencing in a semicircle around culvert intakes to reduce maintenance. Drains can also be used in conjunction with fences if the presence of beaver can be tolerated (Laramie 1963).

Cleaning out beaver-plugged culverts takes time. David Johnson (personal communication) reported that they use a portable, gasoline-powered water pump to hydraulically remove plugs from culverts. Laramie (1963) described another method that uses a vehicle-mounted winch for this purpose. A concrete reinforcement rod is used to thread a rope through the plug. The rope in turn is used to pull the winch cable through the plug. A short log (15 cm shorter than the culvert diameter) is attached at its center to the cable. The cable is then winched through a snatch block below the culvert outlet to pull the log and plug through the outlet end of the culvert. The log is removed, the rope is used to pull the cable back through the culvert, the log is reattached, and the process is repeated as necessary. If a mud plug remains, a small diameter tree can be winched through the culvert like a cleaning brush.

Suggestions for More Permanent Solutions

To repeat a previous point, dam repair is an innate behavior that is triggered and directed by acoustic, visual, and tactile cues. So any structure that permanently solves problems with beaver must control the water level without the sound, sight, and feel of escaping water. As a preventive measure, it should also restrict access to the structure, especially if the feel of escaping water still exists.

I offer the following suggestions solely on the basis of my understanding of beaver behavior, not because I have implemented them. However, I believe each of these should reduce the stimuli that trigger repair behavior and therefore should reduce or eliminate beaver problems.

Culverts

Culverts are very prone to beaver problems because they produce the sound, sight, and feel of escaping water and are accessible. One potential solution for eliminating these cues might be to attach a short elbow on the intake end of the culvert facing down, with a grate over the opening (removable for cleaning). The immediate area of the elbow should be dug out with a backhoe or other heavy equipment to create a deep hole directly below the intake end of the elbow. This should remove visual cues and reduce acoustic cues and access, but it's not foolproof. (1) Sound would only be attenuated, especially if the water level is controlled by the height of the intake end of the culvert. (2) Beaver would still be able to feel escaping water at the elbow. And (3), although modifying the intake end is most important and probably sufficient, beaver might start repairing the outlet end of the pipe by plugging the pipe directly, extending the dam to include the pipe, or building a new dam below the outlet. The sound of escaping water can be moved to the outlet of the culvert by using this end to control the water level (although this may impede fish movement). Repair activity would be less likely on the outlet end.

On the upstream side tactile cues could be reduced at the elbow by further restricting access to a distance far enough from the intake that they can't feel any current. Observations by Reynolds and Lewis (1976) and Guenther (1956) suggest this is probably necessary. They reported instances of beaver mounding up mud and debris until it eventually reached one intake, even though the intake was 3 m above bottom. Restricting access can be done by fencing, staking, or caging the intake or enclosing it within a pile of rock. I would recommend trying the latter as in figure 5. If a problem develops at the outlet end, the same elbow treatment could be applied there as well, or the outlet could be extended, grated, or fenced.

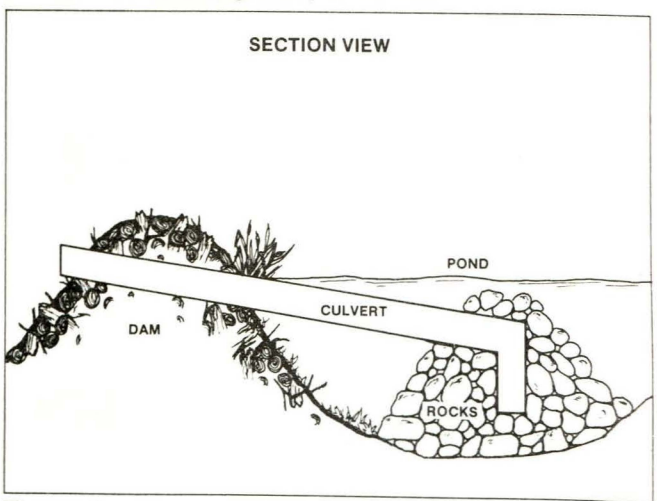

Figure 5.--*A proposed culvert treatment for reducing problems with beaver.*

Another culvert treatment that I tried successfully at one colony was to cover the intake of the culvert with a sheet of plywood so the lower edge was just below the water surface. This removed the appearance of escaping water from the upstream side, although the water was in fact freely flowing out through the culvert. By removing and replacing the plywood, I was able to turn their culvert plugging activities on and off. However, the flow rate of the water was very low, the opening below the plywood was too small for a beaver to enter the culvert, there was little to no sound of water running out the culvert, and there was absolutely no visual cue on the pond surface that water was escaping. Thus this technique may have limited use. It also requires checking and adjustment because it restricts the flow of water (which would be important if the flow rate increased) and it would fail if the water level dropped below the plywood.

Spillways and Adjustable Overflows

Because both of these designs produce the sound, sight, and feel of escaping water, any solution must reduce or eliminate these cues, restrict access, or both. My inclination would be to try installing a vertical baffle off the leading edge of the overflow or spillway so that from the water surface on the upstream side, escaping water would be invisible. Baffle height and length should be sufficient to prevent a view of the escaping water and access to the spillway or overflow. The gap between the leading edge of the spillway or overflow and the baffle should be sufficient for the volume of water anticipated, sufficient to prevent substantial sound of water passing up through the gap, yet too small for a beaver to pass through. A gradual decline from the spillway to a pool rather than a vertical drop over the edge would help reduce the noise of escaping water and therefore attract less attention. Also, it would be desirable to restrict access by staking or fencing the area in front of the baffle, far enough away so that water cannot be felt passing through the barrier.

Drop-tubes or Risers

The drop-tube produces all the stimuli that trigger repair behavior. Aside from temporarily restricting access with fencing, one possible solution would be to add two successive 90° elbows to the intake with a removable grate over the opening so as to create an inverted "J". In this configuration, the intake would be below the water surface and therefore eliminate the appearance of escaping water. The report of Reynolds and Lewis (1976) suggests that this may be adequate. However, the sound of escaping water still would be present because the water is falling down the drop-tube. If sound continues to attract attention, a length of pipe could be installed between the 90° elbows to move the intake far enough from the sound of the water dropping down the vertical tube so they are not as likely to associate this sound with the intake. In either case, it may be necessary to restrict access to the intake by fencing, staking, caging, or enclosing in a pile of rock so that beaver cannot get close enough to feel the escaping water.

Whistletubes

At full pool this design reduces beaver problems, but it is especially prone to them at drawdown. At full pool they apparently still feel the water escaping and plug the intake end, even though sight and sound are absent. The elbow treatment recommended for straight culverts could be applied here along with fencing them far enough away from the intake to eliminate tactile cues. Or, the intake could be buried in a large enough pile of fieldstone so they cannot feel the escaping water (fig. 6). The pile of rock could also be used to form the base for a "push-up" nesting island. This treatment might solve the problem at both full pool and at drawdown.

SUMMARY

1. Waterfowl impoundments generally provide good beaver habitat by meeting their food and water requirements, especially if the shoreline contains hardwood vegetation or aspen, emergents, or aquatic macrophytes in particular. Closed-canopy conifer stands provide poor habitat, thus the only means of making impoundments unsuitable is either to remove all hardwood vegetation (reports give mixed success) or plant a dense stand of conifers. Although hardwood removal has limited applications, establishing dense conifer stands could provide a permanent solution at problem sites.

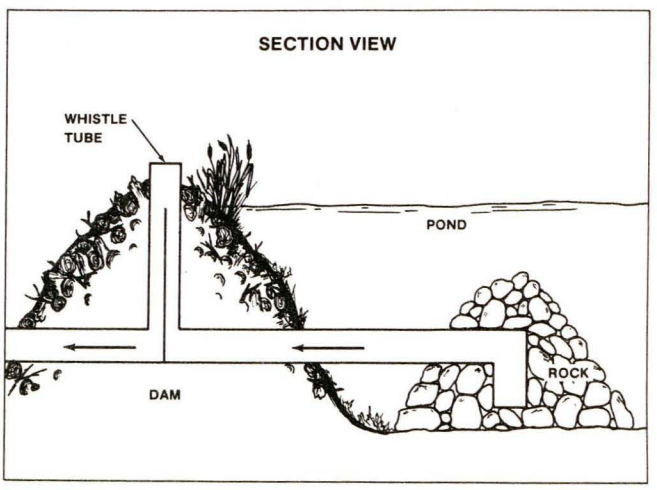

Figure 6.--*A proposed treatment for modifying whistletubes to reduce beaver problems.*

2. Impoundments under 80-100 acres are likely to contain only one family of beaver. The average family contains about five individuals; adults, yearlings, and kits each comprise about a third. Family size averages 3 to 4 individuals in exploited populations.

3. Problems at waterfowl impoundments first occur during April to May or August to September. This is because 2-year-olds diperse soon after spring breakup and families move either before the kits are born or after the kits are weaned. If beaver already occupy an impoundment, problems are likely to intensify as their interest in dam and lodge maintenance increases in August to September. Few if any new problems occur after September.

4. If the impoundment has abundant food resources, beaver families are likely to stay for a number of years. Trapping pressure or low food resources can reduce their stay; often to only a year.

5. Beaver in waterfowl impoundments interfere with the function of water control strurctures. This results from their repair behavior that is triggered and directed by the sight, sound, and feel of flowing water. Thus beaver-proof water control structures must function without producing these cues.

6. Water control structures have five basic designs: (1) Straight Culvert, (2) Spillway, (3) Adjustable Overflow, (4) Drop-tube or Riser, or (5) Whistletube. The inadequacies of each are discussed in relation to the cues produced. Currently, none is adequate to prevent beaver problems.

7. Beaver can be managed by population control, discouraging establishment, and regulating water levels in spite of beaver. Population control methods are only temporary. Methods available for discouraging establishment in forested areas are generally inefffective and probably temporary. The best approach, if solutions can be found, is to design water control sturctures that are beaver proof. This would permanently avoid maintenance problems.

8. Methods for controlling the water level in natural beaver ponds are reviewed. Drains and fencing are useful alternatives for temporarily managing a problem site, but both require maintenance. Suggestions on how to reduce the production of cues that trigger repair behavior are offered for the five basic designs, though none have been tested in the field.

LITERATURE CITED

Almand, J. David, Beaver control. Circ. 565. Athens, GA: University of Georgia, Cooperative Extension Service; 1976. 4 p.

Arner, Dale H.; Mason, Carl; Perkins, Caroll J. Practicality of reducing a beaver population through the release of alligators. In: Worldwide furbearer conference proceedings; 1980 August 3-11; Frostburg, MD: The Worldwide Furbearer Conference; 1981: 1799-1805.

Bergerud, Arthur T.; Miller, Donald R. Population dynamics of Newfoundland beaver. Can. J. Zool. 55: 1480-1492; 1977.

Bradt, Glenn W. A study of beaver colonies in Michigan. J. Mammal. 19(2): 139-162; 1938.

Bailey, Vernon. Beaver habits and experiments in beaver culture. Tech. Bull. 21. Washington, DC: U.S. Department of Agriculture, Bureau of Biological Survey; 1927. 40 p.

Boyce, Mark S. Beaver population ecology in interior Alaska. Fairbanks, AK: University of Alaska; 1974. 161 p. M. S. thesis.

Buech, Richard R. Modification of the Bailey live trap for beaver. Wildl. Soc. Bull. 11(1): 66-68; 1983.

Byford, James L. Beavers in Tennessee: control, utilization and management. Publ. 687. Knoxville, TN: University of Tennessee, Agriculture Extension Service; 1974. 15 p.

Gordon, Kenneth L.; Arner, Dale H. Preliminary study using chemosterilants for control of nuisance beaver. In: Proceedings, 30th annual conference of Southeastern Association of Fish and Wildlife Agencies; 1976 October 24-27; Jackson, MS; 1976: 463-465.

Guenther, Stan. A beaver baffler. Washington State Game Bull. 8(3): 3, 6; 1956.

Hartman, Alan M. Analysis of conditions leading to the regulation of water flow by a beaver. Psychol. Rec. 25(2): 427-431; 1975.

Henry, Dale B.; Bookhout, Theodore A. Productivity of beavers in northeastern Ohio. J. Wildl. Manage. 33(4): 927-932; 1969.

Hibbard, Edmund A. Movements of beaver transplanted in North Dakota. J. Wildl. Manage. 22(2): 209-211; 1958.

Hicks, Tom. Beaver and their control in Georgia. Tech. Bull. WL 2. Atlanta, GA: Georgia Department of Natural Resources; 1977. 23 p.

Hill, Edward P. Control methods for nuisance beaver in the southeastern United States. In: Proceedings, 7th vertebrate pest conference; 1976 March 9-11; Monterey, CA: 1976: 85-98.

Hill, Edward P.; Gardner, Dan T. Beaver control with the Conibear 330 trap. Auburn, AL: Auburn University, Alabama Cooperative Extension Service; 1978. 10 p.

Hodgdon, Harry E. Social dynamics and behavior within an unexploited beaver (Castor canadensis) population. Amherst, MA: University of Massachusetts; 1978. 292 p. Ph.D. thesis.

Hodgdon, Kenneth W.; Hunt, John H. Beaver management in Maine. Game Div. Bull. 3. Augusta, ME:

Maine Department of Inland Fisheries and Game; 1966. 102 p.

Howard, Rebecca J. Beaver habitat classification in Massachusetts. Amherst, MA: University of Massachusetts; 1982. 67 p. M. S. thesis.

Huey, William S. New Mexico Beaver Management. Bull. 4. Sante Fe, NM: New Mexico Department of Game and Fish; 1956. 49 p.

Jackson, Jeffrey J. Controlling beavers on timberland. For. Resour. Note 10. Athens, GA: University of Georgia, Cooperative Extension Service; 1978. 2 p.

Jenkins, Stephen H.; Busher, Peter E. Castor canadensis. Mamm. Species 120; 1979. 8 p.

Johnson, Randall C.; Preacher, James W.; Gwaltney, John R.; Kennamer, James E. Evaluation of habitat manipulation for ducks in an Alabama beaver pond complex. In: Proceedings, 29th annual conference of South East Association Game and Fish Commissioners; 1975 October 12-15; St. Louis, MO; 1976: 512-518.

Laramie, Henry A. A device for control of problem beavers. J.Wildl. Manage. 27(3): 471-476; 1963.

Longley, William H.; Moyle, John B. The beaver in Minnesota. Tech. Bull. 6. St. Paul, MN: Minnesota Department of Conservation; 1963. 87 p.

Miller, James E. Beaver-friend or foe? Circ. 539. Fayetteville, AR: University of Arkansas, Cooperative Extension Service; 1977. 15 p.

Muller-Scharze, D.; Heckman, S. The social role of scent marking in beaver (Castor canadensis). J. Chem. Ecol. 6(1): 81-95; 1980.

Novak, Milan. The beaver in Ontario. Ontario, Canada: Ministry of Natural Resources; 1972. 20 p.

Payne, Neil F. Colony size, age, and sex structure of Newfoundland beaver. J. Wildl. Manage. 46(3): 655-661; 1982.

Pearson, A. M. A study of the growth and reproduction of the beaver (*Castor canadensis* Kuhl) correlated with the quality and quantity of some habitat factors. Vancouver, BC: University of British Columbia; 1960. 103 p. M. S. thesis.

Peterson, Ronald P. Nuisance beaver biology and control in north-central Wisconsin. Stevens Point, WI: University of Wisconsin; 1979. 56 p. M. S. thesis.

Retzer, John L. Physical environmental effects on beavers in the Colorado Rockies. In: Proceedings, 35th annual conference of Western Association of State Game and Fish Commissioners; 1955 June 16-18; Moran, WY; 1955: 279-287.

Reynolds, Ronald E.; Lewis, James C. Evaluating beaver guards on restricted flow risers of flood control impoundments. In: Proceedings, 30th annual conference of Southeastern Association of Fish and Wildlife Agencies; 1976 October 24-27; Jackson, MS; 1976: 455-462.

Richard, P. B. Le determinisme de la construction des barrages chex le castor du Rhone. La Terre et la Vie 4: 339-470; 1967.

Rutherford, William H. The beaver in Colorado. Its biology, ecology, management and economics. Tech. Publ. 17. Denver, CO: Colorado Game, Fish and Parks Department; 1964. 49 p.

Shelton, Philip C. Ecological studies of beavers, wolves, and moose in Isle Royale National Park, Michigan. Lafayette, IN: Purdue University; 1966. 308 p. Ph.D. thesis.

Slough, Brian G.; Sadlier, R. M. F. S. A land capability classification system for beaver (*Castor canadensis* Kuhl). Can. J. Zool. 55: 1324-1335; 1977.

Smith, Albert E. Effects of water runoff and gradient on beaver in mountain streams. Ann Arbor, MI: University of Michigan; 1950. M. S. thesis.

Svendsen, Gerald E. Patterns of scent-mounding in a population of beaver (*Castor canadensis*). J. Chem. Ecol. 6(1): 133-148; 1980a.

Svendsen, Gerald E. Seasonal change in feeding patterns of beaver in southeastern Ohio. J. Wildl. Manage. 44(1): 285-290; 1980b.

Taber, R. D.; Cowan, I. McT. Capturing and marking wild animals. In: Giles, R. H., ed. Wildlife Management Techniques. Washington, DC: The Wildlife Society; 1969: 277-317.

Van Hoey, Alger F. Controlling nuisance beaver. Mange. Ser. 13. Indianapolis, IN: Indiana Deparment of Natural Resources; n.d. 14 p.

Verry, Elon S. Selection of water impoundment sites in the Lake States. In: Water impoundments for wildlife: a habitat management workshop. Gen. Tech. Rep. NC-100. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1985: 31-38.

Wilsson, Lars. Observations and experiments on the ethology of the European beaver (*Castor fiber* L.). Viltrevy 8(3): 115-266; 1971.

Woodward, David K.; Hair, Jay D.; Gaffney, Brian P. Status of beaver in South Carolina as determined by a postal survey of landowners. In: Proceedings, 30th annual conference of the Southeastern Association of Fish and Wildlife Agencies; 1976 October 24-27; Jackson, MS; 1976: 448-454.

Yeager, Lee E.; Rutherford, William H. An ecological basis for beaver management in the Rocky Mountain region. In: Transactions, 22d North American Wildlife conference; 1957 March 4-6; Washington DC: Wildlife Managment Institute; 1957: 269-299.

MANAGING WATERFOWL IMPOUNDMENTS FOR FISHERIES

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"In prehistoric times, Wisconsin was dotted with great numbers of extensive sphagnum bogs. Most of them are now dead and are preserved in the form of great flat peat lowlands varying in extent from a few hundred acres up to many square miles. Unlike the living peat bogs, the soil and consequently, the water, in these lowlands is sweet, and in damp places, productive of pond weeds, tuber-bearing plants, and wild rice. In many places, the peat is underlain by marl or blue clay, but even where there is nothing but sand, the state of decomposition of the peat is such as to be productive of numerous forms of duck foods. Most of these areas are too wet to be of value as agricultural lands and too dry for ducks, Drainage projects have been established in some areas at great expense. Many of these have been unsuccessful. That these areas have potential waterfowl breeding and feeding value has been proved in instances where flooding has been tried. . . . water-level restoration in these areas is needed, not only as an emergency duck measure, but in a far-sighted program for duck marsh conservation."

These were comments made by Homer T. Sowls and John T. Emlen, junior engineer and junior biologist, respectively, in 1934, as field crew for a Wisconsin marshland survey conducted under the supervision and counsel of Aldo Leopold and M. D. Pirnie. Sowls and Emlen felt many of the areas they had surveyed could be improved for waterfowl by building relatively small, inexpensive dams to raise and control water levels. Some areas that had no flowing stream or no good dam site would require excavation of channels and ponds.

They had observed old mill dams on some sites and had learned from local residents that when flooded, these areas were heavy duck breeders and good "pickerel" lakes. They also observed carp in the river systems of the marshes surveyed and expressed concern that carp would affect the growth and spread of vegetation, and even constitute a threat to low impounding structures.

The survey of 1934 made note of the two basic fish management issues still of consequence to fish managers today; managing waterfowl impoundments for game fish, and managing waterfowl impoundments to control rough fish.

The surveys terminated with management recommendations for each area having promise. Their reports included:

1. location of the area
2. general description
3. ownership and land values
4. history of water level manipulations
5. reflooding and water supplies
6. game values
7. local sentiment
8. recommendations and alternatives
9. limitations.

CURRENT MANAGEMENT CONSIDERATIONS

Master Plans

In the mid-70's, the Wisconsin Department of Natural Resources instituted a master plan process for state properties. It was reasoned that these properties provided opportunities to satisfy a variety of public interests. Public pressures were increasing and it became imperative that we maximize user opportunities. Master plans were to be prepared for each property to ensure its basic purpose was achieved and that other public uses consistent with that purpose could be accommodated. Master plans reflect the public interest in all ecological, economic, and social benefits that may be derived from a particular property, consistent with its resource capabilities and the statutes or other constraints under which it was acquired.

Master plans are structured somewhat similar to the old marshland survey plans:

1. goals, objectives, and additional benefits.

2. recommended management programs
3. background information
4. resource capabilities and inventory
5. management problems
6. recreation needs and justifications
7. analysis of alternatives.

Environmental Impact Statements

The Wisconsin Environmental Policy Act (WEPA), which became effective in 1972, requires that an environmental impact statement be prepared for any major action that significantly affects the quality of human environment. These statements closely follow guidelines issued by the U.S. Council on Environmental Quality.

Actions of lesser significance require an environmental impact assessment. Both are subject to public review, constituting another process whereby those who use the resource participate in its managment.

Impact statements repeat most elements of a master plan, though the emphasis may be somewhat changed:

1. introduction containing the proposed action, purpose and history of the project
2. details of proposed action and identification of alternatives
3. description of the affected environment; physical, biological, social and economic
4. consequences of the proposed action on each part of the environment
5. alternatives to the proposed action.

WATERFOWL IMPOUNDMENT MANAGEMENT

Goals and Objectives

Waterfowl impoundments may commonly be features of a public property being managed for its maximum potential as a waterfowl area, primarily for ducks, while providing hunting, trapping, fishing, education, and other compatible recreation opportunities. In other instances, the goal may be restated to manage, preserve, and protect the fish and wildlife resources and their habitats for optimal fish and wildlife based recreation, education, and production, consistent with property capabilities. Regardless of the exact goal statement, it is readily apparent that fish and fishing are considered valid resources of a waterfowl impoundment.

Specific objectives for impoundment management are normally quantified:

1. to produce 0.6 ducklings per acre
2. to provide _____ hunter days
3. to provide _____ trapper days
4. to harvest _____ muskrats (3/ac)
5. to provide _____ dog trial/training days
6. to maintain breeding populations of _____ species
7. to provide _____ angler days
8. to provide _____ participant days of hiking, etc.

Examples of specific objectives for several Wisconsin impounded wildlife areas are provided in table 1. It is well to note that no direct relationship exists between impoundment size, total user days, and angler days.

At this point, the true capability of the impoundment is evident. If the property manager has assessed local interest, existing conditions and resource capabilities, the objectives will reflect this and provide targets to satisfy public interests.

Management is usually a team effort, involving wildlife manager, fish manager, forester, warden, etc. The fish manager, who normally quantifies the fish management objectives for the impoundment, will be quick to recognize those problems associated with reaching his objectives.

Problems and Strategies

Exotics

Carp adversely affect fish objectives as well as waterfowl objectives. They discourage establishment of waterfowl food plants by their bottom feeding behavior. They create turbid water conditions, which, in turn, limit the success of more desirable sightfeeding predator fish, and reduce light penetration essential for growth of vegetation. Carp may physically displace more desirable fish by simply competing with them for space.

Table 1.--*Specific management objects for three Wisconsin wildlife areas with waterfowl impoundments*[1]

Activity	Sheboygan marsh	Horicon marsh	Grand river marsh
Waterfowl hunting	3,500	20,000	12,000
Deer hunting	4,000	3,000	1,500
Other hunting	1,300	3,700	1,750
Trapping	1,000	4,000	1,500
Fishing	4,000	3,000	2,500
Snowmobiling	4,000	3,000	500
Hiking, viewing, etc.	4,000	24,300	3,000
Total	13,800	61,000	22,750
Water area	1,000 acres	6,000 acres	3,000 acres

[1]Expressed in annual user days, based on Department of Natural Resources Master Plans.

The most effective strategy is to chemically eradicate the entire fish population, to prevent reinfestation by using barriers, and to reintroduce desirable fish species. Chemicals most commonly employed are rotenone and antimycin. Rotenone has been most effective when applied immediately before freeze-up. This allows the toxin to take effect and still detoxify while the entire water body is under ice cover.

Impoundments that are regularly drawn down provide an opportunity for controlling re-entry of carp by using either mechanical or electrical barriers alone.

Commercial harvest of carp from waterfowl impoundments has been practiced since the 1920's. Harvest from a single impoundment may be hundreds of thousands of pounds annually. Generally such harvest is ineffective in eradicating or even significantly reducing the carp population. Carp removal with nets may disrupt aquatic vegetation and decrease the attractiveness of an impoundment for waterfowl if done at inappropriate times.

Often the property manager is confronted with rough fish harvest as an objective which does not contribute to the original goals of the management plan.

Low Oxygen Levels

Low oxygen levels (3 mg/l) may favor carp, bullheads, and green sunfish, but eliminate more desirable game fish such as bass, bluegill, and northern pike except during the seasonal migrations to the impoundment for spawning.

Maintaining sufficient oxygenated water in shallow water bodies is both difficult and costly. It may be possible to dredge pockets and channels to provide oxygenated refugia. Dredging should be done at about 20-year intervals because the pond sediments are usually light and mobile, and organic sediments can build up rapidly.

It is also possible to aerate existing ditches and pockets. This process is effective, but costly. A single aeration station may cost as much as $35,000 to purchase and install, and $3,000/year to operate. Aeration is most effective when initiated early in the winter, however, this increases the overall cost proportionately.

Managing waterfowl impoundments at the highest possible water level throughout the year would provide the most fish habitat and highest natural oxygen levels, but would have obvious adverse impacts upon waterfowl habitat.

Dewatering Practices

Periodic partial drawdown may be needed to rejuvenate emergent marsh vegetation. On large waterfowl areas, the wind/wave action across expances of open water sometimes dislodges "islands" of marsh vegetation. Partial drawdowns are conducted every 5-7 years, depending on the rate of vegetation loss.

Partial Summer Drawdowns.--The effect of partial summer drawdowns depends to a great extent on the depth, duration, and frequency of the drawdowns. A complete drawdown over an extended time would concentrate the fish, leading to increased competition, emigration, disease, and angling mortality. More young fish would die as they are forced out of shallow nursery areas. Large predators would migrate upstream if possible. With reflooding, immigration back into the impoundment would compensate for this loss. Downstream or upstream movement of large predators during drawdown may increase predation on intolerant stream fisheries. Another negative result of drawdown would be increased winter biological oxygen demand from increased vegetation, causing more severe reduction in dissolved oxygen levels.

There are some positive effects of drawdown on fisheries. Depth may increase due to sediment compaction. Fish growth may increase during drawdown when prey are more vulnerable, and after drawdown as unoccupied habitat is reflooded. northern pike reproduction may increase as desirable vegetation is reflooded before the spring spawning period.

Full Summer Drawdowns.--These would, of course, magnify both the positive and negative impacts upon the fishery. If a full drawdown resulted in major reductions in adult fish populations at least 3 to 4 years of high water levels would be required for the fish to reach their previous population.

The most practical strategy is to have a partial drawdown for periodic rejuvenation of marsh vegetation without adversely affecting the fish population. Such drawdowns should be timed so as not to seriously affect other objectives of impoundment management.

Shallow Water in General

Waterfowl impoundments without discernible channels or pockets and that rely on seasonal runoff to maintain the water level, are not suited for fish management. Such ponds have no areas that would support fish over winter and would require annual stocking. Aeration would be of questionable value because the oxygen demand of extensive shallow vegetated areas might surpass the ability of aeration equipment.

Without sufficient watershed, shallow, poorly fed impoundments experience water level fluctuations that may be detrimental to both fish and wildlife. The watershed to impoundment ratio commonly used in designing stable waterfowl impoundments is 15:1.

MANAGEMENT CONCLUSIONS

Fish management is frequently compatible with waterfowl management. Where practicable, the mixture of management practices is mandated by public desires and Department policy. When asked to prioritize those activities that should be managed for on one large waterfowl area in Wisconsin, users interviewed produced the following list:

1. hunting upland game (birds)
2. hiking
3. bird watching
4. fishing
5. canoeing
6. hunting waterfowl
7. trapping
8. cross-country skiing
9. outdoor recreation.

Fishing holds a significant position in users' priorities. We can manage for fisheries provided the water is either deep enough or the exchange rate is great enough to provide well oxygenated winter refugia, provided measures to insure over-winter survival of fish are not too costly, provided water level manipulations to benefit waterfowl do not seriously affect fish populations, and provided that is what the public wants.

Costs of various management practices are provided in table 2. Costs are representative of several sizes of impoundments and are based on experiences in Wisconsin during the period of 1976-1982.

Table 2.--*Potential costs for fish management remedial practices*

Activity	Current rate estimates (1982)	Experiences		
		Sheboygan marsh	Horicon marsh	Grand river marsh
Aeration	\$5-10,000 for compressor and pipe. \$2-300/month of operation/200 acres		\$35,000 Installation \$3,000/operation/year.	
Fish Stocking	\$1.75/1,000 northern pike at less than 100,000/acre \$3.80/100 largemouth bass at 100/acre			\$4-5,000/year.
Chemical treatment	\$7.00/acre foot with late fall treatment (4.4° C & 0.75 pmm) at \$25,000/treatment[1]			
Treatement and stocking				\$10,000 (1076) \$26,000 (1979)
Dredging	\$1.25 - 2.00 yd^3 dry or hydraulic. Dependent on proximity of disposal site and magnitude of project	\$2.95/yd^3	(1981)	
Electrical barrier			\$15,000 installation \$2,000/operation/year	\$4,000 (1979)
Fish trap				\$1,495 (1979)

[1]Late Fall Application Recommended Water Temp. 4.4° C.
Rates:
Alkalinity of
1- 35 ppm Tox. Conc. 0.5 ppm
35- 70 ppm Tox. Conc. 0.75 ppm
70-100 ppm Tox. Conc. 1.00
100 ppm Tox. Conc. 1.00-2.00 ppm
Need 2 boats, 4 people/100 acres

CLASSIFYING WETLANDS ACCORDING TO RELATIVE WILDLIFE VALUE: APPLICATION TO WATER IMPOUNDMENTS

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Freshwater wetlands are among the most productive wildlife habitats. They produce an abundance of waterfowl species such as mallards (*Anas platyrhynchos*), ruddy ducks (*Oxyura jamiacensis*), and coots (*Fulica americana*) plus numerous songbirds such as red-winged blackbirds (*Agelainus phoenicesus*) and yellow warblers (*Dendroica petechia*). Wetlands also provide habitat for various mammalian species such as muskrat (*Ondatra zibethicus*) and beaver (*Castor canadensis*).

While wetlands are among the most productive wildlife habitats, they also are being lost at an alarming rate. Weller (1981) estimated wetland losses to agricultural and urban development at 1 to 4 percent annually. Given these trends, wetland managers could benefit from information relating to wildlife use of wetlands and wetland classification schemes for wildlife. Such information would also assist them in protecting high quality wetlands habitats and in formulating management strategies. In this paper I discuss the attributes most strongly associated with wildlife use of wetlands in north-central Minnesota and then show how these attributes can be used in two classification schemes that assess relative wildlife value of individual wetlands. These concepts can also apply to water impoundments.

WETLAND ATTRIBUTES ASSOCIATED WITH WILDLIFE USE

Considerable research has been conducted to determine what wetland attributes have the greatest attraction for wildlife. Many different attributes have been investigated. For example, Beecher (1942) and Kendeigh (1948) found bird utilization of habitat strongly correlated with vegetative structure. Hunt and Naylor (1955) also found habitat utilization by ducks correlated with certain vegetative conditions. They found that vegetative diversity and proximity to water were more important to nesting ducks than vegetative type alone.

Recent studies have stressed the importance of wetland spatial attributes. Weller and Spatcher (1965) found bird numbers and diversity in marshes strongly correlated with the ratio of open water to vegetated area. Maximum bird numbers and diversity occurred when there were nearly equal amounts of open water and vegetation ("hemi-marsh"). There is also evidence suggesting that a wetland's value as wildlife habitat is influenced by its juxtaposition to other water bodies. Golet (1972) reported that a wetland's value to wildlife is generally higher if it is located near other wetlands.

Below I describe how various wetland attributes influenced the use of 28 natural wetlands in the Chippewa National Forest, north-central Minnesota, by more than 80 species of birds. From 4 to 30 species of birds use an individual wetland according to breeding bird surveys conducted during May and June, 1980-1981.

Size

In general, the larger the wetland the higher the number of wildlife species it can support. Figure 1 shows the relationship between wetland size and avian species richness for wetlands in the Minnesota survey. The number of avian species increased sharply with increased wetland size but began leveling out once wetland size exceeded 4 hectares. Similar trends were reported by Probst (1979) for other avian communities.

Juxtaposition

Juxtaposition is closely associated with size. Indeed, several small wetlands in close proximity can often be thought of as one large wetland complex.

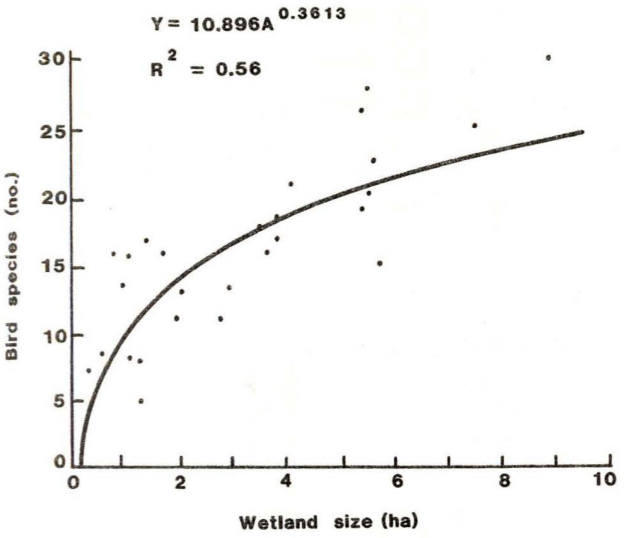


Figure 1.--*Relation between wetland size and avian species richness for wetlands in north-central Minnesota.*

Each of the 28 wetlands surveyed was classified as either "isolated" or "clustered" to determine which was used by more bird species. (Isolated wetlands were located more than 0.25 miles from 2 or more other wetlands while clustered wetlands were located less than 0.25 miles from 2 or more other wetlands). In general, clustered wetlands supported more bird species than isolated wetlands (fig. 2).

What makes wetland clusters attractive to more bird species is not clear; increased vegetative diversity may be a factor. Because wetlands disrupt forest cover and promote shrub growth, birds may be responding to greater variation in vegetative structure. Two to three different wetland types close by each other seem to create the heterogeneity in avian breeding and feeding areas needed to maintain high species diversity (Weller 1978).

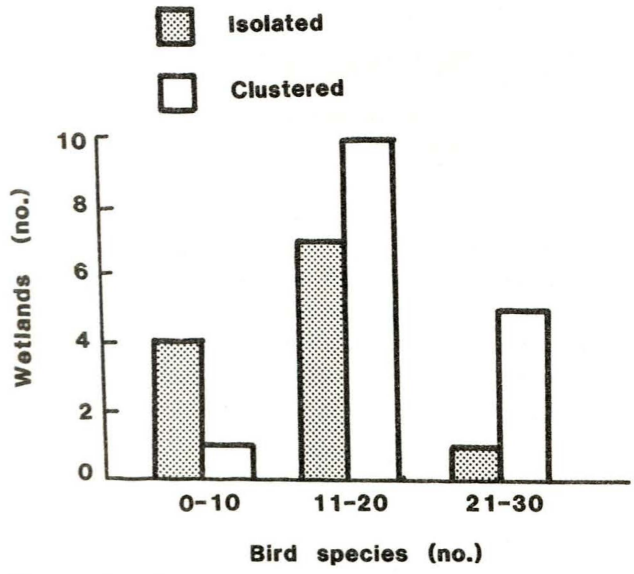


Figure 2.--*Relation between wetland clustering and avian species richness for wetlands in north-central Minnesota.*

Plant Community Richness

My work in the Chippewa National Forest suggests that plant community richness (i.e. the total number of plant communities occurring within or immediately adjacent to a wetland) influences use by birds. Plant community descriptions adopted for this study were provided by Cowardin and Johnson (1973).

While the number of bird species was found to increase with the number of plant communities present (fig. 3), the number of species levels off rapidly to about 15 in wetlands having 7 or more plant communities.

Additional evidence that the diversity of plant communities influenced use by birds was found in the wetland perimeter. Pine (*Pinus* sp.) stands are less vegetatively diverse and provide fewer breeding and feeding sites. Thus the number of bird species declined where pine stands dominated more than 25 percent of the wetland perimeter (fig. 4). Bird species were most numerous where mixed hardwoods or aspen (*Populus* sp.) surrounded the wetland.

Snag Abundance

Snags are generally recognized as an important component of forest avian habitats. Scott *et al.* (1977) estimated that about 85 species of North American birds either nest or roost in dead or deteriorating trees. In addition, many other species utilize snags as perches or feeding sites.

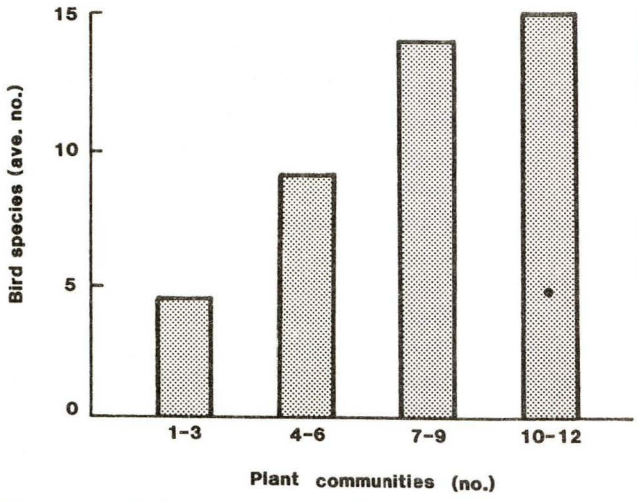


Figure 3.--*Relation between plant community richness and avian species richness for wetlands in north-central Minnesota.*

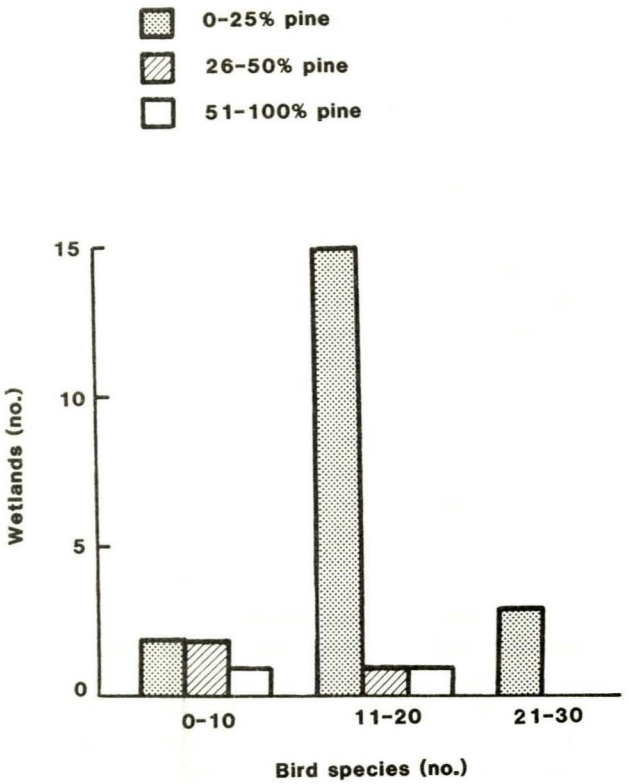


Figure 4.--*Relation between percent pine perimeter and avian species richness for wetlands in north-central Minnesota.*

Given the importance of snags to many species, it seemed plausible that avian species richness would be associated with wetland snag abundance. This was indeed the case. In general, the number of bird species was higher in wetlands having more than three snags per hectare (fig. 5).

Water-Cover Ratio

Some investigators (Weller and Spatcher 1965, Golet 1972) have suggested that the ratio of open water to vegetated surface area influences wetland wildlife. My results show some agreement with these findings but they also suggest that water-cover ratio may be less important in forested areas than in others. For example, of the 7 wetlands in my survey providing habitat for 20 or more avian species, 5 (71 percent) had wetland cover types 4 or 5, the types assigned greatest wildlife value in Golet's wetland classification scheme. Because these cover types have cover plants occupying 26-75 percent of the wetland area, these findings are also in agreement with those of Weller and Spatcher (1965). However, if all 28 wetlands are included, there is no significant relation between avian species richness and percent open water (fig. 6.)

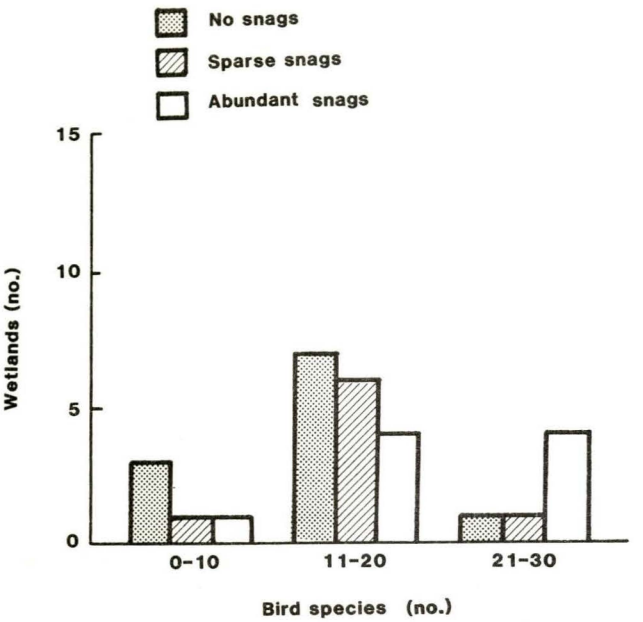


Figure 5.--*Relation between snag abundance and avian species richness for wetlands in north-central Minnesota.*

The weak association between water-cover ratio and species numbers in my survey may reflect the nature of the wildlife community. Golet (1972) designed his wetland classification scheme to evaluate habitat for water-dependent species such as waterfowl and muskrat. Likewise, Weller and Spatcher's (1965) findings reflected habitat selection by marsh birds. Because passerines made up a large percentage of the wildlife community I investigated, one might logically expect to find a weaker association between water-cover ratio and species numbers.

Water Permanence and Chemistry

Water permanence and chemistry are two other wetland attributes used by Kantrud and Stewart (1977)

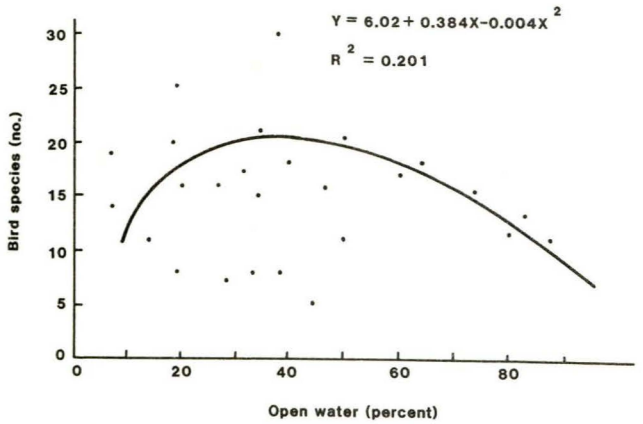


Figure 6.--*Relation between water-cover ratio and richness for wetlands in north-central Minnesota.*

in their studies of waterfowl use of prairie potholes in North Dakota. They found that waterfowl displayed strong affinity for those potholes that were seasonally flooded, presumably the result of higher aquatic invertebrate populations (Swanson and Meyer 1977). Similarly, water chemistry measurements such as pH and conductivity are also used to assess wetland wildlife value (Wheeler and March 1979).

I found neither water permanence nor water chemistry (pH and conductivity) strongly associated with numbers of bird species for wetlands in the Chippewa National Forest. Again, these findings may reflect the fact that waterfowl species represented only a few of the species in the wildlife community I investigated.

METHODS OF ASSESSING RELATIVE WILDLIFE VALUE OF WETLANDS

We have identified some important ecological conditions that influence wildlife use of wetlands. This is important information for management and planning but the manager may be more interested in knowing how alterations (e.g., changing water-cover ratio) increase or decrease the wildlife use of that wetland. For this, we must employ a quantitative scheme that gives a measure of the wetland's value to wildlife based on ecological variables. Several such schemes have been proposed but I will restrict my discussion to two such schemes, one developed by the U.S. Fish and Wildlife Service (FWS) and the other by the U.S. Army Corps of Engineers (COE). These two systems appear to have widest applicability and therefore offer greatest potential assistance to the impoundment managers.

Major Assumptions

Both the FWS and the COE habitat classification schemes are based upon two assumptions. The first is that the quality of fish and wildlife habitat can be expressed as a numerical index that reflects biotic and abiotic conditions associated with a given wetland. The second assumption is that habitat numerical scores give a general indication of habitat carrying capacity. Habitat suitability indices then are generally thought to express the relation:

$$\text{Habitat Quality Index} = \frac{\text{Populations Associated with Current Habitat Conditions}}{\text{Populations Associated with Optimal Habitat Conditions}}$$

Fish and Wildlife Service Method

Since 1974, the FWS has been developing and refining a set of quantitative procedures land managers can use to assess wildlife habitat quality. The procedures, called Habitat Evaluation Procedures (HEP), have been used most extensively by land managers to assess wildlife impacts arising from land-use changes but they could be used equally effectively to develop wetland management strategies.

The FWS system computes a habitat suitability index (HSI) for a particular habitat from habitat suitability models developed by wildlife biologists. These suitability models are typically developed for individual wildlife species and consist of a collection of curves, each curve depicting the functional relation between a given habitat attribute and habitat value for that wildlife species. As an example, the curves comprising the habitat suitability model for wood ducks (*Aix sponsa*) are provided in figure 7. Once the manager has inventoried a given wetland, he can use these curves to assess the wetland in terms of (1) food value, (2) aquatic habitat value, (3) cover value, and (4) reproductive value for wood ducks. Building upon the concepts of limiting factors and habitat quality, relative habitat value will be the smallest of these four values.

To better understand how the HEP system is applied, let us consider a hypothetical set of wetland attributes (table 1). The computations associated with our example illustrate that the lowest suitability index (0.79) is associated with reproductive value of the wetland. Thus, reproductive requirements are most limiting and we consequently assign this particular wetland a relative value (on a scale of 0.0 to 1.0) of 0.79.

While our example deals with a single wildlife species, the FWS system allows managers to combine assessments for several wildlife species into a single, overall habitat assessment. The basic idea is to compute the total number of "habitat units" represented by the habitat. One habitat unit equals 1 hectare of habitat having an HSI score of 1.0 (i.e. a habitat capable of supporting maximum population densities). We obtain total habitat units by multiplying the HSI value times total habitat size and summing the products for all wildlife species. To illustrate, if the wetland habitat we considered above were 200 hectares is size, it would represent 158 (200 times 0.79) habitat units for wood ducks. If similar computations revealed that the area also provided 160 habitat units for mallards, 105 habitat units for

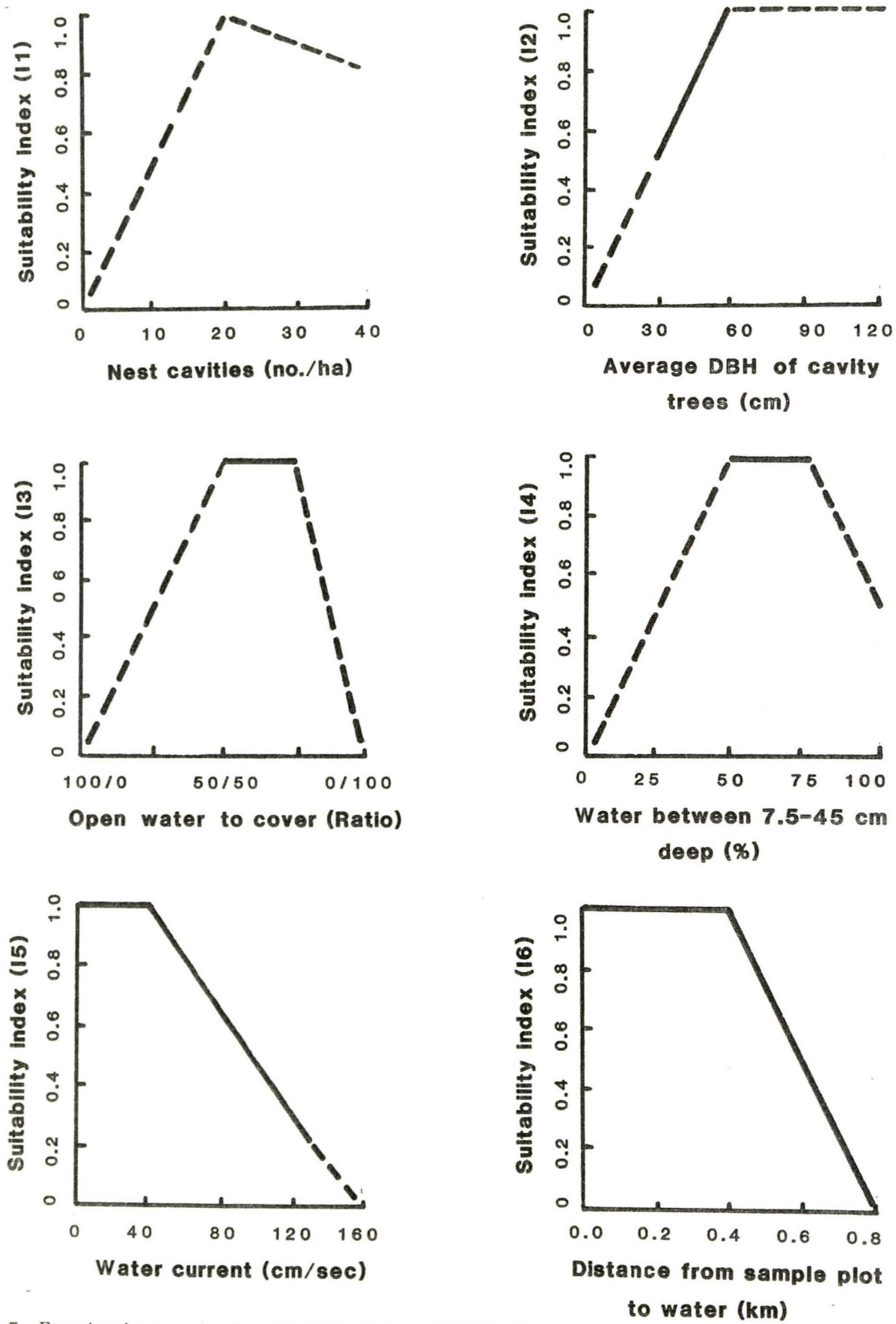
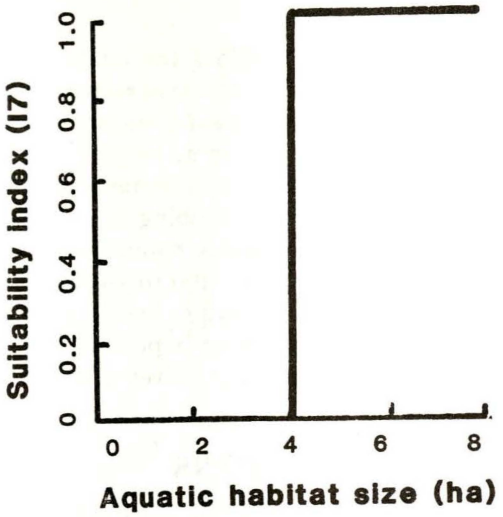
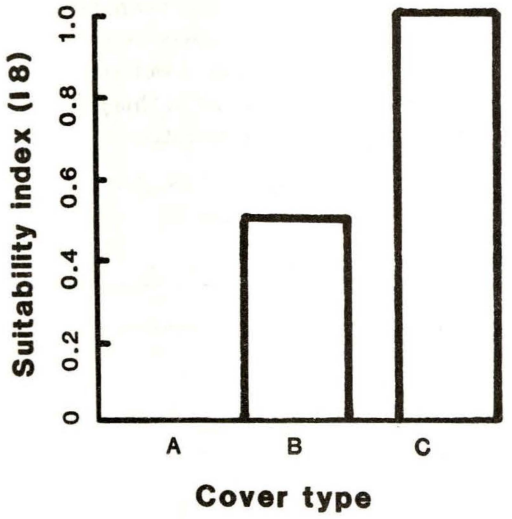

Suitability index (I1)
0 0.2 0.4 0.6 0.8 1.0
0 10 20 30 40
Nest cavities (no./ha)
Suitability index (I2)
0 0.2 0.4 0.6 0.8 1.0
0 30 60 90 120
Average DBH of cavity trees (cm)
Suitability index (I3)
0 0.2 0.4 0 6 0.8 1.0
100/0 50/50 0/100
Open water to cover (Ratio)
Suitability index (I4)
0 0.2 0.4 0.6 0.8 1.0
0 25 50 75 100
Water between 7.5-45 cm deep (%)
Suitability index (I5)
0 0.2 0.4 0.6 0.8 1.0
0 40 80 120 160
Water current (cm/sec)
Suitability index (I6)
0 0.2 0.4 0.6 0.8 1.0
0.0 0.2 0.4 0.6 0.8
Distance from sample plot to water (km)

Figure 7.--*Functional curves developed by U.S. Fish and Wildlife Service to evaluate wood duck habitat.*

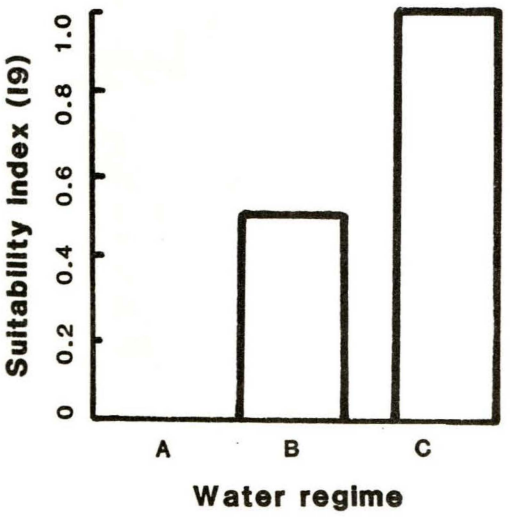
(Figure 7 continued)



Aquatic habitat must be at least 4 ha in size and either a single water body or a group of water bodies each at least 0.1 ha in size and within 0.4 ha of each other.



A - No cover
B - Emergent herbaceous vegetation or downed timber only
C - Herbaceous and woody emergent plants 39-69 cm above the water surface. May also include downed timber.



A - No water or ephemeral flooding
B - Water available at least from mid-January to late September but not permanent
C - Water permanent

Table 1.--*Example illustrating the U.S. Fish and Wildlife Service habitat evaluation method for wood ducks*

I. HABITAT PARAMETERS

No.	Description
I1	No. nest cavities per acre
I2	Ave. DBH cavity trees
I3	Ratio open water to cover
I4	Percent water 7.5 - 45 cm deep
I5	Water current (cm/sec)
I6	Distance to water (km)
I7	Aquatic habitat size (ha)
I8	Cover type
I9	Water permanence

II. FORMULAS

Food Value	$= (I3 \times I4)^{0.50}$
Aquatic Value	$= (I5 \times I7 \times I9)^{0.33}$
Cover Value	$= (I3 \times I8)^{0.50}$
Reproductive Value	$= (I1 \times I2 \times I6)$

III. CALCULATIONS

Habitat parameter	Field data	Suitability[1] index
I1	20	1.0
I2	30	0.5
I3	60:40	0.8
I4	60	1.0
I5	0	1.0
I6	0	1.0
I7	4	1.0
I8	C	1.0
I9	C	1.0

[1]From curves in figure 7

Food value	= 0.89
Aquatic value	= 1.00
Cover value	= 0.89
Reproductive value	= 0.79

muskrat, and 110 habitat units for beaver, then the wetland would provide a total of 533 wildlife habitat units. Habitat suitability models have been developed by FWS for many wildlife species nad are available in the form of habitat evaluation handbooks (e.g. Flood, *et at.* 1977).

Corps of Engineers Method

The U.S. Army Corps of Engineers (COE) has also developed in recent years a method of classifying fish and wildlife habitats accoiding to relative value. Unlike HEP, the COE method, called Habitat Evaluation System (HES), does not treat individual fish and wildlife species. Rather, habitat characteristics are used that indicate habitat quality for fish and wildlife resources as a whole (U.S. Army Corps of Engineers 1980).

Like HEP, HES also determines the quality of a given habitat type from functional curves relating habitat quality indices (HQI) from the functional curves. Each HQI is then assigned a weight, ranging from 0 to 100, which reflects the relative importance of that particular habitat variable in describing overall habitat quality. Weighted scores of key habitat variables are then summed and divided by 100 to yield an aggregate HQI. An example showing how the HES method would be applied to water-impoundments is provided in table 2; the functional curves used in the example appear in figure 8.

CONCLUSIONS

Considerable knowledge has been compiled regarding the relation between biotic and abiotic conditions associated with a particular wetland and wildlife use of that wetland. Much effort has also been devoted to developing methodologies that managers can use to quantify the relative wildlife value of wetlands. In addition to the two methods discussed in this paper, Golet (1972) has developed an innovative system for

Table 2.--*Example illustrating the U.S. Army Corps of Engineers habitat evaluation method*

I. HABITAT PARAMETERS

No.	Description
P1	Mean lake depth (ft)
P2	Turbidity (Jackson Units)
P3	Total dissolved solids (ppm)
P4	Chemical type
P5	Shore development index
P6	Spring flooding index
P7	Fish standing crop (lbs/ac)

II. CALCULATIONS

Habitat parameters	Field data	HQI[1] score	Weight[2]	Weight HQI
P1	60	0.78	15	11.7
P2	200	0.40	15	6.0
P3	500	0.80	20	16.0
P4	3	0.80	5	4.0
P5	30	0.97	5	4.8
P6	1,000	0.60	20	12.0
P7	200	0.90	10	9.0
			100	63.5

[1]From figure 8.
[2]Assigned by COE

Total Weight HQI = 63.5/100
= 0.64.

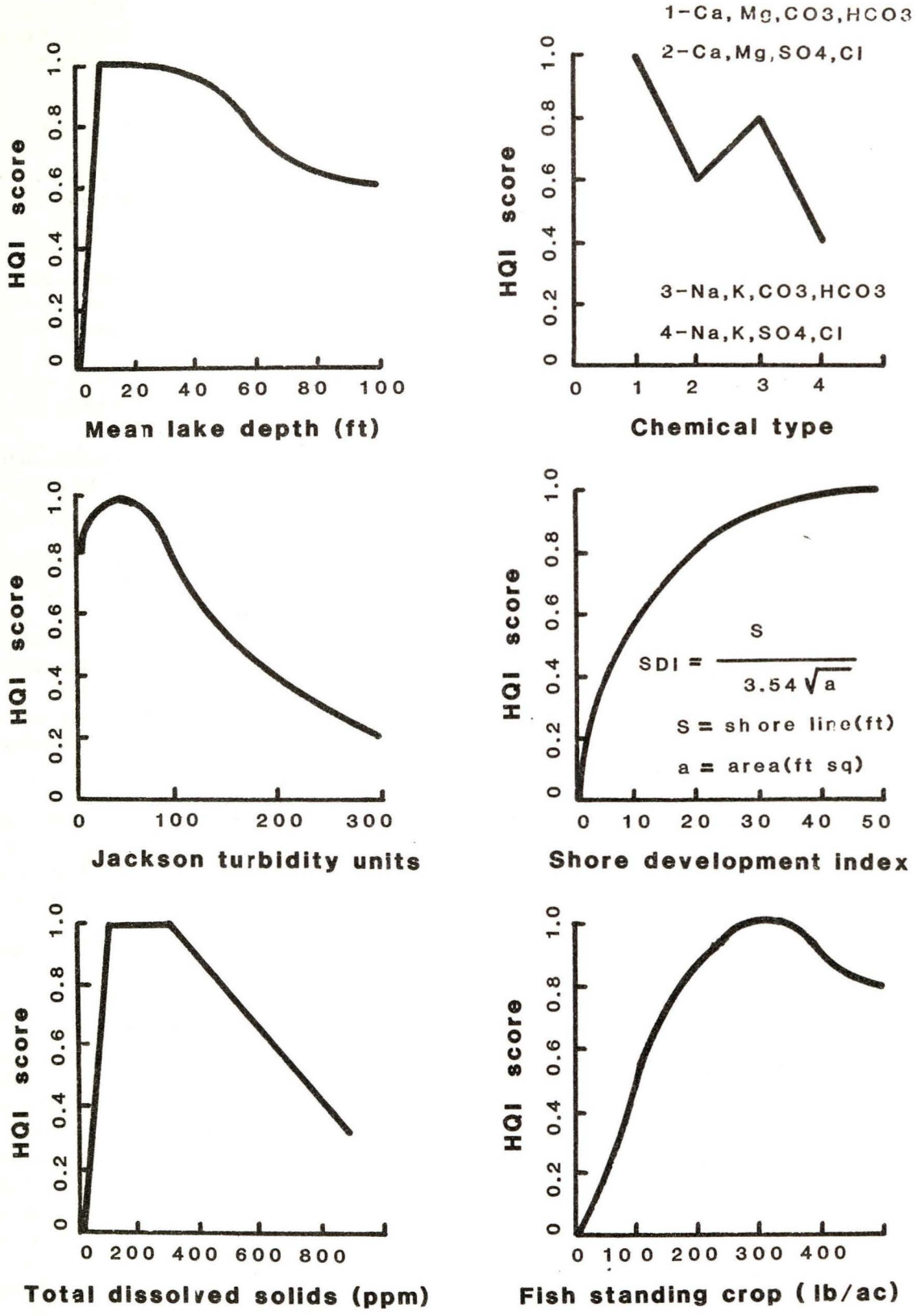
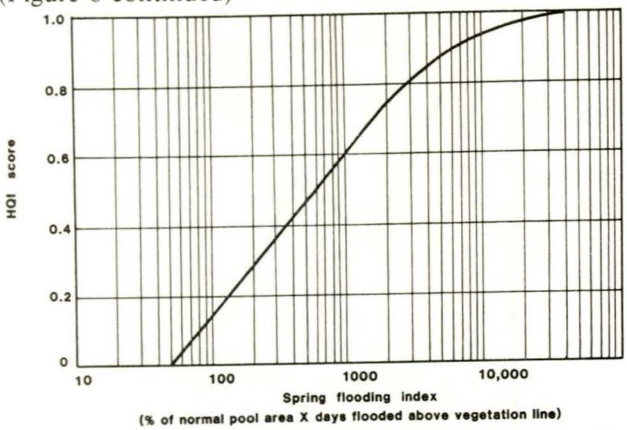

HQI score
0 0.2 0.4 0.6 0.8 1.0
0 20 40 60 80 100
Mean lake depth (ft)
1-Ca, Mg, CO3, HCO3
2-Ca, Mg, SO4, Cl
3-Na, K, CO3, HCO3
4-Na, K, SO4, Cl
0 1 2 3 4
Chemical type
0 100 200 300
Jackson turbidity units
SDI = S / 3.54 √a
S = shore line(ft)
a = area(ft sq)
0 10 20 30 40 50
Shore development index
0 200 400 600 800
Total dissolved solids (ppm)
0 100 200 300 400
Fish standing crop (lb/ac)

Figure 8.--*Functional curves relating six habitat variables to habitat quality indices (HQI).*

(Figure 8 continued)



classifying wetlands in the northeastern U.S. according to wildlife value. All of these efforts have potential for enhancing the management of artificial impoundments for wildlife. Some important guidelines derived from these works follow.

In order to successfully develop or modify water impoundments to benefit wildlife, the manager must first know which wildlife species the impoundment is to attract. If waterfowl are primary, then water-cover ratio, impoundment age, and water conditions that promote the production of macro-invertebrates (e.g., water chemistry, soil fertility, and water depth) will likely be most important. If on the other hand, wildlife diversity is desired, these factors are less important.

Wildlife diversity is closely associated with habitat diversity. Thus, if possible, impoundments should be constructed as several smaller units rather than one large unit. Such a design would enhance wetland clustering and habitat diversity, thereby promoting maximum wildlife use. Design would also have to be compatible with other social and economic goals associated with the impoundment.

Nearly all species of wildlife have special habitat requirements that must be filled if populations are to achieve maximum levels. Snags, for example, are needed by many species of passerines. These requirements must be identified before development is started so they can be integrated into the overall design.

Finally, and perhaps most importantly, impoundment managers should remember that nearly all of our knowledge related to wetlands and wildlife has been gained through the study of *natural* wetlands. We do not know to what extent this knowledge can be transferred to artificial impoundments. In other words, we have no assurances that constructing impoundments around guidelines developed from the study of natural wetlands will lead to comparable wildlife use on man-made wetlands. Some research has been conducted to determine waterfowl use of artificial potholes in the midwestern U.S. However, until such research is expanded and applied to other wildlife species and types of impoundments, it will be difficult to formulate construction guidelines that will promote wildlife use.

LITERATURE CITED

Beecher, W. J. Nesting birds and the vegetative substrate. Chicago, IL: Chicago Ornithology Society; 1942. 69 p.

Cowardin, L. M.; Johnson, D. H. A preliminary classification of wetland plant communities in north-central Minnesota. Spec. Sci. Rep. 168. Washington, DC: U.S. Fish and Wildlife Service; 1973. 33 p.

Flood, B. S.; Sangster, M. E.; Sparrowe, R. D.; Baskett, T. S. A handbook for habitat evaluation procedures. Res. Publ. 132. Washington, DC: U.S. Fish and Wildlife Service; 1977. 77 p.

Golet, F. C. Classification and evaluation of freshwater wetlands as wildlife habitat in the glaciated northeast. University of Massachusetts. 1972. 180 p. Unpublished Ph.D. dissertation.

Hunt, E. G.; Naylor, A. E. Nesting studies of ducks and coots in Honey Lake Valley. Calif. Fish and Game 41: 295-314; 1955.

Kantrud, H. A.; Stewart, R. E. Use of natural basin wetlands by breeding waterfowl in North Dakota. J. Wildl. Manage. 41: 243-253; 1977.

Kendeigh, S. C. Bird populations and biotic communities in Northern Lower Michigan. Ecology 29: 101-114; 1948.

Probst, J. R. Oak forest bird communities. In: Management of north-central and northeastern forests for nongame birds. Gen. Tech. Rep. NC-51. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1979: 80-88.

Scott, V. E.; Evans, K. E.; Patton, D. R.; Stone, C. P. Cavity-nesting birds of North American Forests. Agric. Handb. 511. Washington, D.C.: U.S. Department of Agriculture, Forest Service; 1977. 112 p.

Swanson, G. A.; Meyer, M. I. Impact of fluctuating water levels on feeding ecology of breeding blue-winged teal. J. Wildl. Manage. 41: 426-433; 1977.

U.S. Army Corps of Engineers. A habitat evaluation system for water resources planning. Vicksburg, MI: 1980. Lower Mississippi Valley Division; 1980: 89 p.

Weller, M. W. Estimating wildlife and wetland losses due to drainage and other perturbations. In: Richardson, B., ed. Selected Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board; 1981: 337-346.

Weller, M. W. Management of freshwater wetlands for wildlife. In: Goode, R. E.; Whigham, D. F.; Simpson, R. L. eds. Freshwater wetlands: ecological processes

and managemnt potential. New York: Academic Press; 1978: 267-284.
Weller, M. W.; Spatcher, C. S. Role of habitat in the distribution and abundance of marsh birds. Spec. Rep. 43. Agriculture and Home Economics Experiment Station, Iowa State University of Science and Technology; 1965. 31 p.
Wheeler, W. E.; March, J. P. Characteristics of scattered wetlands in relation to duck production in S.E. Wisconsin. Tech. Bull. 116. Madison, WI: Wisconsin Department of Natural Resources; 1979. 61 p.

THE PUBLIC'S USE AND PERCEPTION OF WATER IMPOUNDMENTS FOR WILDLIFE

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Wildlife impoundments or floodings have a long history in Michigan. Water levels in the 850-acre Bentley Marsh in Gladwin County were raised by the improvement of a roadway dike in 1934. Davenport (1959) reported, however, that the first dam construction project took place, also in 1934, at Backus Lake in Roscommon County. The Reedsburg, Dam creating the 2,170-acre Deadstream Flooding in Missaukee and Roscommon Counties was completed in 1940. These few units were the first major wildlife floodings (> 100 acres each) of a list that now encompasses 118 units totaling some 41,300 acres (fig. 1). In addition to these

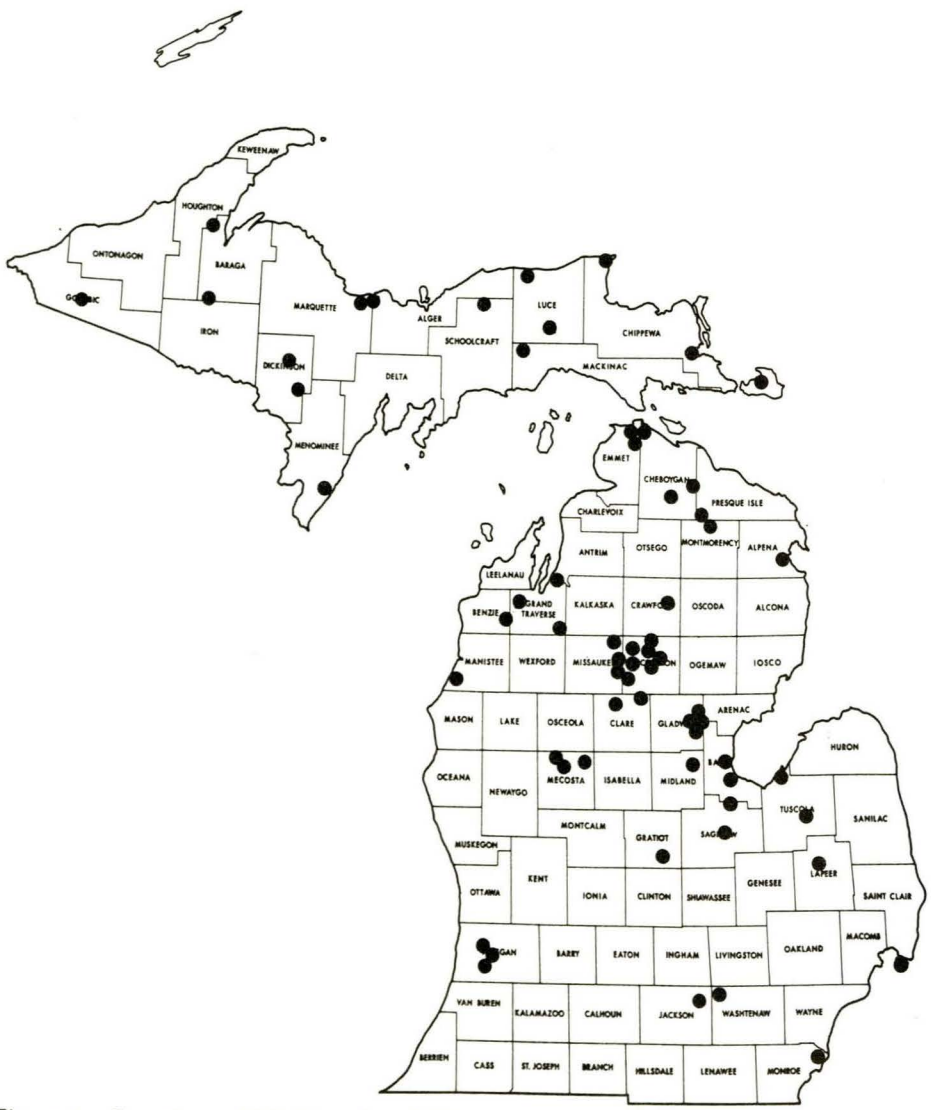

Figure 1.--*Locations of Michigan's wildlife impoundments of 100 acres or more (118 units constructed, 1934-1982; 41,300 acres.*

major floodings, Michigan has constructed over 450 minor wildlife floodings (< 100 acres each) that total an additional 4,200 acres, mostly in southern Michigan.

The history of development of major wildlife impoundments (100 acres plus) in forested areas of Michigan is shown in the following tabulation:

Years	Number of impoundments	Total acreage
1926-1935	2	1,490
1936-1945	1	2,170
1946-1955	25	12,710
1956-1965	18	7,459
1966-1975	8	5,547
1976-1982	9	1,180

Most of the major forested area floodings were funded and constructed by the Department of Natural Resources Wildlife Division from 1950 through 1974, some 51 units totaling 26,000 acres. Primary funding for these projects was derived from the Pittman-Robertson Fund and the State's Game and Fish Protection Fund. However, a number of recent cooperative projects include substantial, or even primary, funding from the Soil Conservation Service and from the Dignell-Johnson Fund.

The typical Michigan wildlife impoundment in forested areas has been created by construction of a low-head concrete dam with one or more stoplog bays for control of water levels. The dam was usually situated across a creek or river channel that traversed herbaceous meadow or brush or timbered swamp. Frequently the dam was placed at the same site as old beaver dams or logging dams. Earthen dikes of various lengths connect the dam to the nearest high ground and an emergency spillway is typically situated in the dike near the dam. A smaller number of impoundments have been constructed with radial gates in the dams and the most recent impoundment has a fish passage ladder.

Interior improvements were constructed within the shallowest areas of some impoundments by dragline or bulldozer, including level ditches, potholes, and waterfowl nesting islands. Brush and trees were sometimes removed from interior islands or upland edges to enhance waterfowl nesting opportunities. Fluctuation of water levels, primarily drawdowns to re-establish cover plants or food species, has been the major ongoing management technique employed on a periodic basis on these floodings.

The dependability of the water source at each flooding has varied depending upon characteristics of the watershed and the engineering employed. In some cases, it has been difficult to refill impoundments during late summer or early fall after a prolonged drawdown.

Burning of accumulated vegetation or dead timber and some millet seeding, has also been practiced during drawdowns. In the last 10 years, small open meadows have been created along the upland edges of some floodings to provide herbaceous browse to enhance local goose production and migrant goose use. Scheduling of drawdowns and other management improvements has typically been left to the initiative of each local biologist.

Major duties of the Michigan Department as stated by its charter laws are to protect and conserve the State's natural resources, foster and encourage the protection and propagation of game and fish and to provide and develop facilities for outdoor recreation. The past and current program for development and maintenance of wildlife impoundments fits these criteria quite well.

PUBLIC USES OF WILDLIFE IMPOUNDMENTS

Michigan's experiences in wildlife flooding management may not be unique from that of other midwestern States; however, Michigan is a populous State with 9.2 million, mostly urban residents (1980 census). Most major wildlife floodings are within 4 hours' driving time of the State's large urban centers. Michigan residents have been accustomed to traveling for outdoor recreation and the State also hosts many tourists attracted to the outdoor scenery and variety of outdoor recreational opportunities. Tourism, is in fact, the State's number three industry. People, therefore, do have a significant influence on management of the State's wildlife impoundments.

Boss (1976) studied human uses of the Maple River wildlife impoundment in southern Michigan and the Townline Creek impoundment in the north central part of the Lower Peninsula. He determined from postcard questionnaires that the public engaged in a minimum of 16 activities over the 11-month period from March 1974 through January 1975. Most prominent of these activities were hunting, fishing, trapping, birdwatching, and hiking (table 1).

Miscellaneous activities listed included boating, parking, photography, private study, picnicking, and dog exercise. Birdwatching was popular only on the Maple River Flooding which is about 30 miles north of Lansing and adjacent to and in open view of a primary interstate highway.

Belyea and Lerg (1976) reported 35 human activities for southern Michigan waterfowl project areas encom-

Table 1.--*Two Michigan wildlife impoundments March 1974 to January 1975*[1]

Activity	Maple River (Southern Michigan)		Townline Creek (Northern Michigan)	
	Weekday	Weekend	Weekday	Weekend
	----------*man hours/acre/100 sample days*----------			
Bird watching	0.02	0.71	--	--
Boating-canoeing	--	.13	--	--
Bow fish-spearing	.05	.29	--	--
Exercising dog	--	.06	--	--
Fishing, general	.02	.33	0.07	--
Fishing, ice	.04	--	--	--
Hiking	.11	.53	--	--
Hunting, deer	--	.03	.02	--
Hunting, upl. game	--	--	--	0.04
Hunting, waterfowl	1.72	5.29	--	.65
Misc. collecting	.01	--	--	--
Parking	.02	--	--	--
Photography	.02	.08	--	--
Private study	--	.04	--	--
Picnicking	.01	--	--	--
Trapping	.42	.45	--	.02
Total	2.44	7.94	.09	.71

[1]Adapted from Table 13, p. 38 of unpublished M.S. Thesis, Impacts of Permanent Flooding on Two Natural Wetlands in Michigan, 1976, Boss, J. W., Central Michigan University, Mt. Pleasant.

passing the 12-month period of December 1973 through November 1974 (table 2). Hunting constituted 28 percent of the activity hours (mostly waterfowling = 23.9 percent) and non-hunting activities 72 percent. Fishing was the single most important activity--57 percent of all reported activity hours. Camping, boating and boat launching were other significant activities, but nonetheless generated only 10 percent of the activity hours. Overnight camping was prohibited on most of the areas or this activity probably would have been greater.

State Forest campgrounds have been constructed at a considerable number of the northern Michigan wildlife floodings. These campgrounds have been popular sites that have markedly altered the proportion and types of uses on some floodings as compared to the reports by Boss (1976) and Belyea and Lerg (1976).

PUBLIC PERCEPTION OF WILDLIFE IMPOUNDMENTS

In a broad sense activities noted in the studies previously cited reflect the public's perception as to the nature or value of the wildlife impoundments. They also reflect, however, innate characteristics directly related to initial planning: engineering and construction; soils, watershed and water level management; ecological communities and other subsequently imposed physical/cultural developments, such as roads, trails, and campgrounds. Of all activities previously noted, the wildlife impoundment in Michigan is probably most perceived by the public as a fishery resource or a potential fishery resource; this is a State that has 11,000 natural lakes. Secondly, I believe the public perceives them as places to camp, boat, or swim. Thirdly, they are good and interesting places to hunt and trap. Fourth, they are perceived as unique wildlife production areas and places to view unique wildlife including ducks, geese, herons, otters, beavers, ospreys, and eagles. Finally, another group views them as sources of water problems, too much water to upstream residents, or too little water to downstream residents.

These perceptions and those of other special interest groups can be illustrated by examples:

1. Innumerable personal conversations with field biologists reveal that the public has removed or replaced stoplogs on a frequent basis; fishermen, waterfowl hunters, and boaters usually tend to seek increased water levels. Drawdowns seldom seem to be understood by these users or trappers and not at all by campers. Resort owners have attributed decreased pike fishing success in Potagannissing Bay to interruption of spawning runs by the wildlife dam at the Potagannissing Flooding on Drummond Island.

Table 2.--*Recreational activities on southern Michigan waterfowl areas, December 1, 1973 to November 30,1974*[1]

Activity	Estimated people hours	Percent
Total non-hunting	931,856	71.9
Total hunting	364,006	28.1
Grand total	1,295,862	100.0
ITEMS		
Fishing	739,664	57.1
Waterfowl hunting	309,145	23.9
Camping	33,453	2.6
Boating and canoeing	29,931	2.3
Boat launching	27,671	2.1
Target practice	24,618	1.9
Upland game hunting	23,294	1.8
Deer hunting (bow & arrow)	15,750	1.2
Snowmobiling	11,881	.9
Deer hunting (firearm)	10,191	.8
Trapping furbearers	9,484	.7
Sightseeing	9,471	.7
Birdwatching	8,700	.7
Picnicking	6,361	.5
Squirrel	5,731	.4
Hiking	4,663	.4
Non-hunting undifferentiated	4,523	.3
Put-take pheasant hunting	4,418	.3
Pre-hunting activity	4,239	.3
Nature study	3,544	.3
Mushroom picking	2,650	.2
Photography	2,354	.2
Swimming	1,844	.1
Scouting	1,772	.1
Dog training and exercise	1,594	.1
Loafing	1,037	.1
Firewood gathering	663	--
Motorcycling	545	--
Sunbathing	314	--
Undifferentiated hunted	296	--
Fox hunting	296	--
Berry picking	242	--
Cross country skiing	222	--
Miscellaneous collecting	219	--
Water skiing	196	--

[1]Table 2 taken from p. 34, Public Use of Southern Michigan Game and Recreation Areas, 1976, Belyea, G. Y. and J. M. Lerg, Wildlife Division Report #2754, Michigan Department of Natural Resources, Lansing, Michigan.

2. In Benzie County, upstream residents attribute death of trees on their property to water levels generated by the Grass Lake wildlife flooding. Hydrologists tell us that holding of design levels should not be causing this problem.
3. In Montmorency County sharply reduced levels in a downstream lake were attributed to the holding back of water in the Rainy River Wildlife Flooding. Hydrological records demonstrate that for the fourth time in this century the subject lake emptied into a subterranian limestone sink hole.
4. In Roscommon County, at the South Pike Marsh flooding, burning to control encroaching brush was ruled out by DNR biologists because of perceived problems with the public including the potential for smoke hazards to traffic on adjacent highways and the deposition of wind transported ash on nearby lake shore homes and yards. Increases in water levels to control brush were also ruled out because increased flooding against roadway embankments was opposed by County and State highway officials.
5. In Alger County, downstream residents expressed concern for guaranteed water releases to protect stream quality below the Sand River Flooding. Marquette County duck hunters, who had secured a portion of the funding to develop the flooding, opposed installation of an osprey nesting platform on the basis that it would interfere with waterfowl hunting activities.
6. In Bay County, the Tobico Impoundment which has been mostly a waterfowl refuge, has been monopolized by visitors from the adjacent Bay City State Park. Parks interpreters have developed an interpretative display, a marsh boardwalk, and an observation tower.
7. In Mescosta County, the Department of Natural Resources obtained flooding easements from private land owners to complement State land ownership within the flood contours of the planned Martiny Lakes Wildlife Flooding. The 1,420-acre flooding was constructed in 1955. In 1961, landowners and County Commissioners brought suit against the DNR to stabilize water levels under Michigan Law when they were faced with a planned drawdown for wildlife enhancement. Subsequently, the State Supreme Court ruled against the State's claim of legal authority to manipulate water levels for wildlife at this site. Since that time, cottages, resorts, beaches, and campgrounds have fluorished. Resort owners now complain about the presence of introduced resident giant Canada geese on their beaches and lawns and some cottage owners allege that wild rice interferes with their boating access to deeper portions of the impoundment.

SOME BASIC QUESTIONS RELATED TO IMPOUNDMENT PROGRAMS

The previous examples may be useful in examining basic questions; i.e., should wildlife impoundments be single purpose of multi-purpose? Can they be single

purpose? The charter of the Michigan Department of Natural Resources is multi-purpose, but does that mean that every project or program must be multi-purpose? The definition of multi-purpose to the wildlife impoundment manager may simply be the production of ducks and geese for waterfowl hunting and the accommodation of waterfowl hunters during the fall season. He or she may even accept or be heartened by secondary furbearer benefits or the utilization of the impoundment by ospreys.

To the summer tourist, however, the occasional glimpse of an elusive brood of ducks may have nowhere near the thrill of a 2-foot pike on the end of a fishing line. Nor will the duck brood or the osprey have the "meaning" that running up the side of a dike with a trail bike does or toasting marshmallows around the fire at the camping site on the hill overlooking the impoundment. Whose definition of purpose shall be used, that of the wildlife biologist or impoundment user? The impoundment user, depending on background, may not be impressed that hunters' monies paid for construction. If the impoundment resource is on public land with public access, attempts will be made by the general public to use that resource. Since the public's perception of permissible wildlife impoundment uses may vary considerably from that of the manager, public uses must be carefully planned for and guided.

IMPOUNDMENT MANAGEMENT CONCEPTS

An impoundment program must be guided from early on by a set of goals and objectives that includes acceptable public uses and has established the degree to which public utilization can be permitted without seriously jeopardizing the intended functions of the impoundment. It is imperative that the public understand that the management of a productive wildlife flooding is contingent upon uneven water levels, and in fact, little or no water during planned drawdowns. It seems likely that this concept can only be conveyed by a continuous program of public information, starting perhaps with information meetings prior to construction, posting of explicit information signs at access sites, provision of explicit brochures on site and at general locations, periodic news media releases, and of course, actual fluctuation of water levels for specific management purposes. An agency must first however, have a vigorous inhouse program of similar information to make sure that impoundment management concepts and goals are understood, accepted, and properly conveyed to the public. For example, it would be confusing for the public to receive one message from the wildlife biologist, another from the fish biologist, and yet another from the forest campground supervisor.

VISITOR USE AT IMPOUNDMENTS

If the objective(s) for wildlife impoundments include an increase in visitor use, then there are many techniques that can be employed.

First, of course, is to manage the flooding to create those wetland communities that produce a diversity of species and adequate quantities of wildlife to be readily visible.

Second, there is a need for the public to be aware of the location of the impoundments. In a general sense this can be accomplished by providing a comprehensive brochure listing locations, facilities, possible activities, and species of interest. Good driveable roads or trails into impoundments, well-marked with directional signs, will ensure increased visitor use as well as improved parking and boat launch facilities. Impoundments deep enough to support game fish and desirable pan fish species will attract many visitors. Other improvements to be considered include hiking trails, observation towers, wildlife openings, introduction of unique species (e.g.) geese and swans, campgrounds, and even visitor centers, beaches, liveries, and concessions.

It should be obvious that a number of these techniques offer the potential for substantial conflict with traditional wildlife management goals. In particular, these are the physical improvements including the campgrounds, visitor centers, beaches, liveries, concessions, and improved roads. In the proper place, and with proper planning, however, even these facilities may serve a useful purpose. For example, the visitor center at Seney Refuge in Michigan's Upper Peninsula offers an educational message for thousands of tourists each summer about wildlife biology and the need for providing and maintaining wetlands wildlife habitat. Yet it only takes up a small space in a large complex of wildlife impoundments. Perhaps a disadvantage is that resident Canada geese "freeload" on handouts offered by people.

A stormwater, runoff wildlife impoundment in the midst of a well-spaced governmental office complex 8 miles south of Lansing, Michigan (on former farm land) does an excellent job of producing ducks and geese. While the wildlife are exposed to the daily comings and goings of several thousand workers and their auto traffic, natural overlooks permit people to see the marsh without having to intrude into the area. The initial preservation of nesting cover around the marsh by a joint agency management plan was the other ingredient that produced the desired result.

Elsewhere, only a minimally-maintained forest road may be necessary to provide for hunters, trappers, and management personnel when an impoundment is far off the "beaten path," and expenditures of funds to improve visitor use would yield minimum results.

Each agency must decide what public uses are consistent with the primary objectives of their wildlife impoundments. Then, with a combination of: (1) skillful planning, (2) adequate funding, (3) proper positioning of physical facilities, (4) selection of appropriate area rules (including time and space considerations), (5) vigorous rule enforcement, and (6) continuing provision of information for the public, even complex and multi-purpose objectives can be met. The challenge to the agency and the manager is to mesh and carry out these considerations with such efficiency that both people and wildlife will benefit.

DESIGN AND LOCATION OF WATER IMPOUNDMENT STRUCTURES

Glen R. Anderson, *Civil Engineer,*
Chippewa National forest,
Cass Lake, Minnesota

Since 1964, when the Chippewa National Forest began constructing wildlife impoundments, about 50 have been completed. We've been learning as we've gone along--sometimes rather painfully. Often, at the start of this program, as soon as an apparently suitable site had been located, we began surveying. Some surveys were completed, and some wildlife impoundments were designed before we discovered that, for some reason, the sites were unsuitable. We even have one of two "skeletons" in our closet--dams that probably should never have been built.

It is very important that a potential impoundment site be thoroughly studied and evaluated to determine whether or not it is practical and economically feasible. This takes place during a preliminary review, followed by a preliminary survey and design process. Work on sites that survive this evaluation is carried forward to final design and construction.

PRELIMINARY REVIEW

Preliminary review involves the study of available maps, photos, and other documents. Most of the review is done in the office, followed by a brief field investigation. At this point, many sites are eliminated, either because of the lack of drainage area, a poor location for the dam, right-of-way problems, or the high cost of construction.

Several tools that are available to assist in evaluating a site are:

1. U.S.G.S. Topographic Maps
2. Aerial Photos
3. Land Status Maps.

U.S.G.S. Topographic Quadrangle maps show contours with which to delineate and calculate the size of a drainage area. The ratio of drainage area to flooded area is important. A drainage area that is small in relation to the flooded area will result in runoff insufficient to fill the reservoir. A large drainage area, on the other hand, can result in a large and costly structure. Ideally, the ratio should be between 10 and 30; however, other factors--such as subsurface flow--must be considered. If U.S.G.S. maps can be obtained in orthophoto (an aerial photo overlay in color on the map), they will be easier to use. Vegetation types and wetlands are shown on orthophoto maps.

Aerial photos of National Forests, taken periodically in the past, usually show the extent of past flooding by beavers, and give a good indication of reservoir size. No better assurance of site suitability exists than the knowledge that it has been flooded in the past.

While low-level aerial photos are valuable tools in evaluating a site, they later on become even more valuable to the survey crew and designers. These photos should be taken in the spring when the leaves are coming out, so they will show the best contrast between vegetation types.

To determine whether private lands will be affected, land status must be checked; then private landowners must be contacted to see if they are willing to grant an easement. If they refuse, a decision must be made to either pursue condemnation or drop the site.

The purpose of the brief field investigation is to obtain more specific information and to get a "feel" for the site. The engineer will be most interested in checking the dam site to determine whether there is sufficient elevation on the sides, what length of dam is needed, and whether marsh excavation will be required. Often the field investigation will reveal that to proceed is entirely impractical. Other items checked in the field are access roads, borrow pit sites, and emergency spillway locations.

PRELIMINARY SURVEY AND DESIGN

After preliminary review, the next step is preliminary (limited) survey and design. If well planned, the field work can usually be completed in one day by a two-man crew.

During the field investigation, the engineer usually puts up flagging to indicate where he wants the crew

to survey. Low-level aerial photos, when available, can be used very effectively to indicate where surveying should be done. A clear, acetate photo overlay can be used to show a proposed dam site, borrow pit, survey lines, etc. By cutting a line across a proposed dam site, the crew can measure distances, take centerline elevations and check for depth of marsh excavation along the centerline. They can also measure and take elevations along a line extending from the dam upstream to the end of the area proposed for flooding.

The engineer, by plotting and analyzing the field data, can determine within a short time whether a site is suitable and the approximate cost of constructing the impoundment.

It is very important to examine the levels taken along the line which extends upstream from the dam. When elevations change, either too gradually or too rapidly, the effectiveness of an impoundment is reduced. The ideal pool depth for waterfowl is 12 to 30 inches. The ideal pool elevation is one that produces the maximum size pool within this depth range.

When elevations change too gradually, it is possible that too much area--including timber, private lands, and water bodies--would be affected.

When elevations change too rapidly, it is possible that any given pool elevation would flood only a relatively small area to a suitable depth.

Plotting of the dam centerline survey will give information relating to earthwork volumes, structure size, and other features.

The preliminary survey and design will provide the following information:

1. Approximate size of reservoir
2. Size and type of structure
3. Layout of the dam
4. Costs within 10 percent accuracy.

Preliminary survey and design should provide sufficient information to determine whether or not a site is worth developing. If a decision to proceed is made, the final survey and design will be done.

FINAL SURVEY AND DESIGN

Except that they are more detailed and extensive, the final survey and design don't differ much from the preliminary one. Exact reservoir boundaries are determined and elevations are taken throughout the proposed reservoir to determine flooding depths. A detailed survey with soundings is made at the dam site to accurately determine excavation and borrow quantities.

The final design is made with the following in mind:

1. Low construction cost
2. Ease of maintenance and operation
3. Visual attractiveness.

Normal Pool

After elevations have been plotted and contour lines drawn, the normal pool elevation is selected. The area enclosed by each contour line is calculated, allowing the wildlife biologist to select the elevation that will produce the maximum area flooded to proper depth (table 1). Elevations at the sides of the dam and around the reservoir often control the maximum allowable pool elevation.

The height of the dam, elevation of the emergency spillway, and--to a certain extent--the size and type of control structure, depend greatly on selection of the normal pools.

Table 1.--*Sample calculation for determining normal pool elevation*

Contour interval	Acres	Flooding depth (in feet) Normal pool elevation 108	109	110	111
103 - 104	1	4-5	5-6	6-7	7-8
104 - 105	3	3-4	4-5	5-6	6-7
105 - 106	6	2-3	3-4	4-5	5-6
106 - 107	8	1-2	2-3	3-4	4-5
107 - 108	16	0-1	1-2	2-3	3-4
108 - 109	14		0-1	1-2	2-3
109 - 110	7			0-1	1-2
110 - 111	7				0-1

To determine the area flooded to certain depths under various normal pool elevations, enclose the desired range of depths between parallel lines. Then add the acreages flooded for each of the corresponding contour intervals.

Example--Area flooded to 1-3 foot depth

Elevation	Area
108	14 acres
109	24 acres
110	30 acres
111	21 acres

A normal pool elevation of 110 will give the most area flooded to a 1 to 3 foot depth.

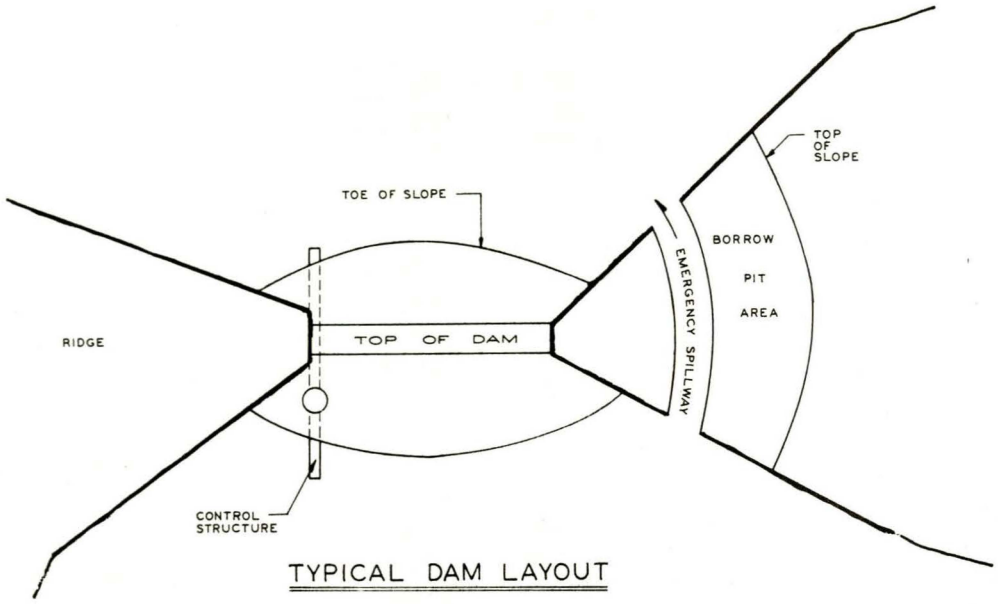

Figure 1.--*Typical dam showing borrow pit and emergency spillway.*

Dam

Unless other factors such as marsh excavation govern, the dam is usually located at the narrowest gap in the flowage. Generally, the best layout is to have the borrow pit next to the dam, with the emergency spillway constructed as part of the borrow pit (fig. 1). Basically, the designer attempts to use as little material as possible and to move it the shortest possible distance.

The design of a dam is governed by the type of material used. To prevent seepage, dams constructed out of sand need flatter slopes than those constructed of clay.

Unless it is to be used as a roadway, the top of a dam is generally 10 feet wide. Because it is difficult to modify a dam for traffic at a later date (by widening and graveling the top), it is very important to know in advance whether a dam will be used as a roadway.

An emergency spillway is used to protect the dam. Generally, the crest elevation is about two to three feet below the top of the dam. Sometimes, with minor modifications, a natural drainage can be used as an emergency spillway.

Water Control Structure

There are two types of water control structures--the whistle tube and the drop inlet (fig. 2). Probably the most common, the whistle tube comes prefabricated in a variety of sizes and is easy to install and maintain. There are several variations of drop inlet construction. It can simply consist of a half-round culvert pipe with a stop-log channel on the front side, or be of concrete construction. Often a tossup, the decision of whether to use a whistle tube or drop inlet is up to the designer or operator.

To reduce the risk of settlement, the structure should not lie on fill material or where a marsh has

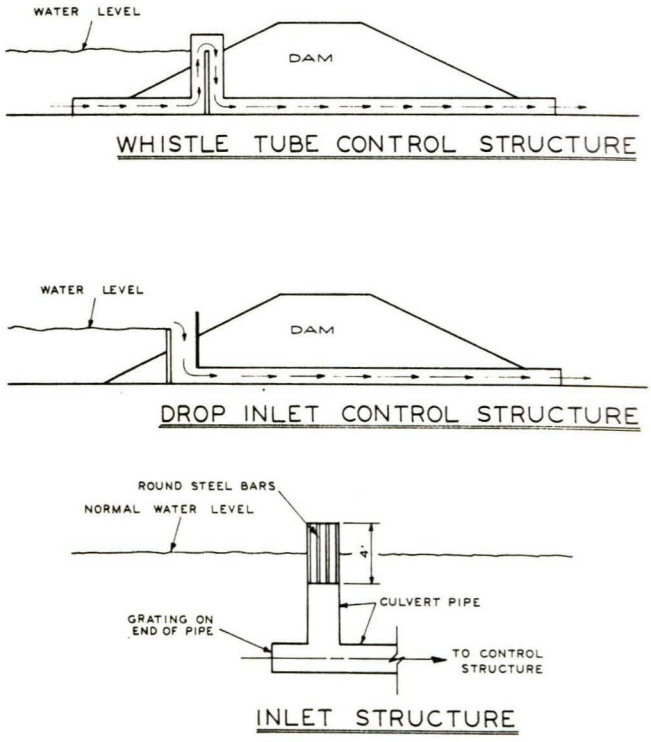

Figure 2.--*Typical water-level control structures.*

been. Often the best location is near the ends of the dam, where the ground is the most solid.

To prevent any leakage from following along the pipe and washing out material, the outlet pipe will have anti-seep diaphragms, and the end of the outlet pipe should be protected with rip-rap.

Proper construction techniques are essential for installing a structure. The bed must be well compacted to proper grade, with the fill compacted in layers around the structure.

Other types of water control structures are possible, and the designer can be imaginative. Two impoundments on the Chippewa National Forest have been constructed in conjunction with existing bridges. Using sheet piling, each was constructed with the entire structure serving as a spillway. These structures will pass large flows of water. In one case, an old bridge was removed and replaced with a timber box culvert. The bottom of the box culvert was set at the desired pool elevation, with a structure installed to drain the impoundment.

Inlet Structures

In an attempt to reduce beaver plugging, several inlet structures have been used with the whistle tube. These have met with limited success. The first design, simply an extension of the inlet pipe, was fitted with a grate on the top and at the end. Because they were often submerged under several feet of water, these became plugged easily and were difficult to clean. Later designs have consisted of vertical inlet structures made of wood or metal. Although they also get plugged, they are easier to clean because they are accessible.

Fish Ladders

Two fish ladders to accommodate northern pike migration have been constructed; one of steel sheet piling, and the other of treated timber. Water velocities were kept low, but for some unknown reason, these were not successful. Northern pike seem reluctant to use them, even though they often jump to get over other obstacles.

SO YOU WANT TO BUILD A WATER IMPOUNDMENT

Robert E. Farmes, *Region I Wildlife Supervisor,*
Minnesota Department of Natural Resources,
Bemidji, Minnesota

The development of an impoundment requires careful planning and strong personal commitment in order to get the job done. I will review some of the necessary steps one must take and discuss some of the problems and considerations involved in the development of a typical impoundment.

RESPONSIBILITY

The first step is assigning responsibility to the proper individual. This individual should possess a thorough understanding of aquatic biology and wildlife management, have a working knowledge of construction methods and equipment, be familiar with the various types of water control structures, and be able to work with all kinds of people under stressful situations. Above all, the person should have established a track record of getting the job done--in other words a doer as well as a good thinker. At the same time he or she must also be able to delegate work and know when consultation with professionals in other disciplines is desirable. Constant and direct communication between the project supervisor and others involved in the planning and design is of utmost importance.

SITING

The site for an impoundment designed to provide waterfowl and other wildlife habitat should have certain characteristics to make a good impoundment. An adequate water supply is most important, so make sure the watershed is large enough to supply these needs. The actual watershed size needed will vary considerably depending on several factors, so it is best to consult a hydrologist about this aspect of site selection.

Make sure the topography of the basin is relatively flat and shallow. Be careful not to select areas that are too flat where water depths will be mostly less than 18 inches. Water too shallow will often result in an impoundment that is overgrown with emergents, providing little open water. Narrowleaf cattail and hybrids of narrowleaf will persist and thrive in water deeper than 18 inches. Water depths of 18 o 48 inches throughout the impoundment will usually result in a desirable ratio of 50-50 open water and emergents. Potential impoundment sites can frequently be determined by observing areas which flood naturally during times of heavy run-off. Aerial observations followed up by ground reconnaissance during spring run-off will often give a person some ideas for potential sites. Photos of these naturally flooded sites will be of value during the planning stages, and U.S. Geological Survey quadrangles can be most helpful during feasibility studies.

Soils are an important consideration in site selection. Generally those areas with the more fertile soil types provide conditions for preferred growths of aquatic vegetation and invertebrates. Poor soils should be avoided unless the water source provides additional nutrients.

Floating bogs are a special problem. In some areas that are impounded the vegetative mat simply lifts up, forming a floating bog. If no open water remains, little has been accomplished. In other cases only portions of the vegetation will lift forming a good interspersion of cover, islands, and open water. A "Cookie Cutter," a machine that will cut up the floating bog and provide the open water, is useful in some of these situations.

Whenever an impoundment is built, certain species of wildlife will be replaced by others. Make sure the trade-off is desirable and the gains will be greater than the losses.

FEASIBILITY SURVEY

If there remains any question about the site, you should request an engineering feasibility survey. This request might include topographic or hydrological information or a preliminary cost estimate. Final plans and specifications should not be requested until you are relatively sure the project is feasible from a cost, construction, and land control standpoint.

LAND OWNERSHIP

Surprisingly, land ownership is often overlooked even though it may seem obvious that land control is

necessary. Time and money may be spent planning a project only to find out the impoundment will affect land that you cannot buy or obtain a flowage easement on. This aspect of planning should be determined as soon as possible and no later than at the time of the feasibility survey.

PERMITS

Permits are usually required by State agencies regulating surface waters. Usually permit applications call for specific information, so plans and specifications need to be submitted along with the application. It is recommended that these applications be made as soon as the project is determined to be feasible and when plans and specifications can be provided.

The Department of Natural Resources, Division of Waters, administers the permit process in Minnesota. Permits are required when (1) lakes; (2) natural water courses with a watershed over 2 square miles; or (3) wetland types III, IV, and V (USF&WS Circ. 39) over 10 acres (2½) acres in municipalities) are affected. Applications are made to the regional hydrologist.

The Dam Safety section in the Division of Waters also reviews plans to assure that construction meets dam safety requirements.

In addition, the Pollution Control Agency and the State Archeologist review permit applications in Minnesota. The State Archeologist will often require an archeologicl survey prior to construction. All persons, corporations, and governmental units are required to have permits.

Another permit may also be required if legal drainage systems are affected. Applications in these cases should be submitted to the ditch authority which may be the County Board, the Watershed District, or the District Court depending on the kind of ditch system involved.

In Wisconsin, the Department of Natural Resources regulates the permit system for dam construction and regulates and controls the level and flow of water in all navigable waters. Navigable waters in Wisconsin are defined as: Any stream capable of using a recreational craft for any purpose on a regular recurring basis. The DNR also determines methods of construction, operation, and maintenance for any dam. Permits may be issued to any person, firm, corporation or municipality. Applications setting forth details of construction are submitted to the Department District Water Management Coordinator along with a basic $10 fee, plus supplemental fees depending on project value. Federal agencies are exempt from State permit requirements, but State and other units of government are not exempt.

Michigan has several laws affecting dam construction. One or all of the following may apply to any particular project:

1. Dam Construction Approval Act of 1963
2. Inland Lakes and Streams Act of 1972
3. Inland Lake Level Act of 1961
4. Passage of Fish Over Dams Act of 1979
5. Goemare-Anderson Wetland Protection Act of 1979
6. Soil Erosion and Sedimentation Act of 1972

All but the last are administered by the Michigan Department of Natural Resources. A permit consolidation process now allows one application to cover the first five acts. Applications are to be sent to the Land Resource Programs Division at Lansing.

Applications must include plans and specifications prepared by a registered engineer. Michigan charges a fee ranging from $200 to $600 depending on the size of the project. Everyone must go through the permit process, but fees are waived for State and federal agencies. All applications go through a public notice procedure.

The Soil Erosion and Sedimentation Act is administered by county and township boards. Apparently all impoundments come under the provisions of this act. In general this act requires that proper erosion and sedimentation practices be incorporated into the construction, operating, and maintenance plans.

In addition to a State permit, a federal permit has been required for most impoundment construction in the past. The U.S. Army Corps of Engineers regulates the discharge of dredged or fill material into the waters of the United States through Section 404 of the Federal Water Pollution Control Act of 1972. Generally a federal permit has been required if wetlands or other bodies of water over 10 acres in size were affected by fill or dredged material. However, recent changes have been approved by the Office of Management and Budget which removes the 10 acre limit and now all "isolated" waters will come under a nationwide permit. This means individual permits are not required in States where nationwide permits have been approved and anyone may place fill or dredged material in these so called isolated waters without a federal permit.

PREPARING PLANS AND SPECIFICATIONS

The supervisor in charge of the project may or may not be involved in the details of construction design depending on his/her particular experience and whether or not an engineering staff with design experience is readily available. As a minimum the project supervisor should have an opportunity to review plans and specifications. Since elevations and drawdown capability are extremely important, this aspect of design should be reviewed very carefully. Make sure structures are designed to accommodate the highest normal pool elevations you believe will ever be desired. Water elevations can always be lowered, but once the structures are built, higher elevations are impractical without additional construction. When reviewing the plans and specifications *do not take anything for granted.*

The dike elevation should be three feet above maximum normal pool elevation allowing for one foot of bounce and two feet of freeboard during flooding. Dike top width and side slopes can vary somewhat depending on head of water, dike materials, and budget considerations. On small impoundments a minimum top width should be eight feet and side slopes 3:1; larger projects should have a 12 to 15 foot top and at least 4:1 side slopes.

Water control structures should be designed to allow a maximum of one foot of bounce over normal pool elevations. All structures should be designed so that heavy equipment can readily travel the dike for maintenance and emergency repairs. The principal structure should be designed to allow for water level manipulation as well as complete drawdown.

Projects with large watersheds usually incorporate emergency spillways into the design in order to handle periods of heavy run-off. These should become operational when one foot above normal pool is reached. Emergency spillways are designed to release floodwaters that are surplus to what the principal structure is designed to take. These may be simply a low spot in the dike heavily rip-rapped with field rock, or in cases where erosion is a problem, steel sheet piling may be driven down the center of the heavily rip-rapped area. In extreme cases, concrete spillways may be needed to prevent erosion and failure of the spillway.

CONSTRUCTION

The question of whether to do the work by private contractor or with your own crew and equipment is usually determined by budgets, equipment, and personnel available. When given a choice, I prefer the private contractor. Cost comparisons show that on the larger projects contractors will often do the job for less than with your own work force and you will not have a lot of your labor force tied up on one project.

If the work is done by private contractor it is advisable for the project supervisor to call a pre-construction conference between the contractor, the engineer, and any others involved in the planning and design of the impoundment so that everyone understands what the plans call for.

Agencies must usually obtain bids if the project is done by contract. Bids may be called for in a number of ways. The project may be bid in one lump sum, but if this is done a very complete set of plans and specifications needs to be furnished to potential bidders. Often it is an advantage to separate out the earth work form the control structures because many contractors have expertise in only one or the other or these areas. In this way you will obtain more bids and likely get the job done at less cost.

If you ask for separate bids on the earth work, it may be bid in one lump sum, by the cubic yard, or by the hour. If bid by the hour you must furnish good specifications on the equipment you wish to rent. Usually crawler tractors with scrapers, crawlers with dozers, draglines, or a combination of these are used. *Generally the larger equipment will do the job at less total cost.* Crawler tractors should have power shift with a minimum of 200 flywheel horsepower (D8H-46A or larger). Draglines should have at least a full one yard rating and carry 60 feet of boom. In some cases some of the larger backhoes may be able to replace the dragline. If large amounts of dirt are to be moved by dragline a larger machine in the 2 to 3 yard capacity carrying 80 to 100 feet of boom should be considered (American 700 series or equivalent).

All machines should be equipped with a Servus Recorder (an instrument that records on a paper disk when the machine is operating) when doing hourly work. Payment is based only on the hours recorded. Two things are vitally important when doing hourly work: (1) The machine must fully meet specifications called for and be in good operating condition and, (2) The operator must be fully qualified at operating the machine under similar conditions. It is best to specify that the operator have a certain minimum hours operating the equipment. If the bid is made in a lump sum amount or by the cubic yard, some of the above is not nearly as important.

How do we determine what equipment should be used for the earthwork? When bidding is by the cubic yard or in a lump sum this will be determined by the contractor. If the work is hourly this aspect needs to

be determined before calling for bids. Dozers, dozers with scrapers, and then draglines should be used in that order if soil and moisture conditions permit. Dozers will often move dirt for half the cost of a dragline while dozers with scrapers are somewhere in between, depending on how far the dirt is to be moved. Under wet, heavy soil conditions draglines with mats are usually needed. In some cases low ground pressure (LGP) crawlers can operate; they should be considered unless the area is extremely wet.

Dike construction techniques are important and should be thoroughly understood by the project supervisor. Construction methods will depend, to some extent, on soils at or near the site and the type of equipment used. It is less costly to obtain fill material immediately adjacent to the dike, and it is best to borrow this material from the outside, but if necessary it is permissible to borrow from the pool side. The center of the dike should consist of impervious material to prevent excessive seepage. Where no impervious material is available, a diaphragm embankment may have to be considered as an alternative. Diaphragm embankments are those which incorporate a cut-off wall through the middle of the dike to form a water barrier. Usually steel or wood sheet piling is driven down to an impervious foundation. Another alternative is to line the pool side with a clay blanket a foot or more thick. Both of these alternatives are extremely costly techniques that are recommended only in areas where other methods to prevent seepage are impractical, and where the expected benefits to wildlife are much higher than average. All organic material and debris should be removed from the base of the dike before fill is excavated and in areas of deep peat a core should be constructed. The core trench is excavated to mineral soil and then back filled with clay. If the dike is constructed with dragline, a berm of at least 15 feet should be left between the toe of the dike and the near edge of the borrow pit.

Fill cast up by a dragline should be about 25 to 30 percent greater than required to allow for settling. Material from dragline constructed dikes is usually quite wet and if much clay is involved a year or more may be needed before leveling by dozers can be done. Compacting successive lifts with dragline-constructed dikes is usually not practical because of the wet material. However, unless dike failure would result in loss of life or valuable property, it should not be necessary to meet rigid compaction standards under low head situations. Beefing up the dike may be a cheaper way of treating anticipated seepage problems where seepage may cause dike failure. Final leveling and shaping should be done with a medium-sized motor grader. The dike top should have a slight crown to allow water to run off.

Dike side slopes should be dressed with 2 to 3 inches of organic material to provide a seed bed. Seeding the dike should be done to prevent erosion and to provide food and cover for wildlife. Where dikes are several miles long they can provide an important source of highly nutritious food for a large variety of wildlife. Dikes seeded to a mixture of 2 pounds Parks blue grass to 6 pounds White Dutch clover with oats as a nurse crop and fertilized have been heavily utilized in Minnesota by deer, sharp-tailed grouse, Canada geese, and mallards. Since dikes provide excellent travel lanes for many predators, avoid seeding dikes to nesting cover where ground predators may be a problem. Vegetation with deep tap roots should be avoided as these tend to weaken the dike when the roots die. It usually pays to fertilize with 100 to 200 pounds to the acre with a formula recommended for the soils in the area. When vehicles need to travel the dike frequently, it is advisable to gravel the top, but graveling should be done only in the late fall or winter after the dike has frozen sufficiently. This is especially important on new dikes that are still comparatively soft.

COST CUTTING IDEAS

Most agencies are currently working under tight budgets, but still we should always be looking for ways to get the most out of our wildlife dollars. Here are some ways to stretch the dollar.

Engineering studies can use a large percentage of your construction money. Although highly detailed plans and specifications are necessary and desirable in some cases, they are not always needed. One of the easiest ways to save on engineering costs is to obtain information on areas that flood naturally by viewing them during spring run-off and during periods of heavy precipitation. You may avoid costly topographic work by securing this kind of information. You should plot the extent of flooding and depths over the area.

Large, elaborate water control structures are expensive. You may want to reduce the size of the control structure and provide an emergency spillway that is utilized with greater frequency.

The impoundment can be built in stages if your budget will not allow immediate completion. The principal water control structure may be temporarily eliminated by using the emergency spillway for all run-off. The principal structure can then be installed when funds become available.

If the work is done by contract you can often save considerable money by doing the earthwork by renting equipment with operator by the hour. When working by the hour contractors do not need to build in the

insurance they do when they bid a total price on the job. You also can avoid considerable engineering costs by doing hourly work. The contractor does not need to know, except in very general terms, the cubic yardage to be moved. However, if you decide to bid the earthwork by the hour, you must make sure the contractor has good equipment and will provide a competent operator.

Dam safety engineers will usually require that dikes be built so that a high degree of compaction is obtained. This requires costly construction methods involving soil moisture control and adding material in successive lifts. This type of construction may result in costs 50 percent or more above construction without special compaction. This aspect of construction should be evaluated to see if it is really necessary.

The bidding process is another area where costs may be shaved. Bid invitations should be prepared so that a maximum number of qualified bidders are eligible to bid. Calling for very specialized equipment will usually result in few bids at higher costs. Make sure the job is well advertised. Smaller contractors with fewer overhead costs usually are able to bid jobs lower than the large companies, so make sure your bid bond and other requirements do not rule these out.

Actual construction costs per developed acre can vary considerably. At today's prices most impoundments will run from $200 to $300 per acre. Anything over $500 per acre should be looked at critically to see if there are alternative sites where costs might be lower. If development costs are more than it would cost to buy natural marshes in the area, perhaps the money would be better spent acquiring natural marshes.

From initiation to completion, the planning and construction of an impoundment can be very lengthy. In extreme cases, you may wait several years before all hurdles are cleared. Most, however, are completed within 2 to 3 years. Take one step at a time and don't become discouraged by the bureaucratic processes. If you have a good site, and you have planned properly and have pushed and shoved when needed, you'll get the job done.

SUMMARY AND RESEARCH NEEDS

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The purpose of this workshop was to update information on water impoundments for wildlife and based on this information to prepare a symposium proceedings that will assist managers faced with decisions on why, where, and how to build impoundments, and how to manage them. We will highlight the various papers presented and assess, from our point of view, where the purpose of the workshop was accomplished and where important questions remain unanswered. These unanswered questions form the basis and justification for additional research.

Impoundments are one type of wetland and problems in impoundment ecology can only be understood in the more general context of wetland ecology. Leigh Fredrickson set the stage by giving a rapid review of the variation and complexity of wetland ecosystems. He pointed out that they are curcial to the well being of a number of furbearers, birds, herptiles, and fish. The requirements of these animals for wetland habitat may be short in time but critical to their life cycle. There is still a need for more details of life history information for many species that utilize these impoundments. It is critical for the manager to know which limiting factors are being supplied to the various species that use his impoundments.

Wetland habitats are in jeopardy because of destruction and modification by man and impoundments can be used to mitigate this loss. To function effectively, impoundments must, to some extent, duplicate the natural system that they are to replace. This can only be accomplished by understanding function and dynamics of wetland systems. Unfortunately, though much is known, much remains to be learned. In many cases, adequate research tools have not been developed. We need research that will provide information on how to better predict productivity as part of the site selection process. We also need better information on the subtleties of the impoundment degradation process.

Robert Radtke showed the immediacy of the problem of wetland loss mentioned by Leigh. Because of the high loss of wetlands in agricultural regions of the prairies, wetlands in forested areas will assume a new significance in the battle by federal, State, and local governments and private groups to stem the loss of wetlands. The prospects for achieving stated preservation goals are not bright. If the fight to preserve wetlands is to be won, better coordination among agencies will be essential. Lowell Suring showed that the effort to preserve wetlands is by no means a recent development. The problem of wetland loss was recognized in the 1930's and at that time drained marshes were reclaimed for wildlife. He then traced the history of impoundment development to the present.

The remaining papers were much more specific in nature. They dealt with impoundments in the forested northern Lake States. John Mathisen addresed the difficult question of why we need impoundments on an area like the Chippewa National Forest that has abundant natural wetlands. Drawing on wildlife use data, later illustrated by Donald Rakstad, he assessed whether impoundments meet their objectives. He concluded that impoundments fill wildlife needs that are met by the least common wetland types; therefore, conversion of shrub swamps, sedge meadows to impoundments that simulate seasonal or semipermanent wetland types help meet wildlife management objectives. His assessment was based on a logical procedure where he quantified wildlife value of habitat based on the number of species present and developed a simple method for comparing areas. Gary Williams illustrated another simple method of evaluating habitat, again based on species richness but using different attributes than those used by Mathisen. We still need research to answer questions about values of species richness vs. numbers of individuals of particular species. We cannot assume that an impoundment use by many species is always best. We also need to know if

we see increased use patterns at impoundments because we are helping increase population levels or because we are simply attracting animals from other areas.

With the question of why build impoundments resolved, the remaining papers moved to the question of where and how to build and manage them. Sandy Verry reviewed studies of water quality and illustrated the implications of impounding water on temperature, coliform bacteria, pH and nutrients. He made the perhaps heretical statement that drawdowns do not recycle large quantities of nutrients. The nutrients are released from bottom muds under the ice regardless of water sources or timing of drawdowns. What, then, are the advantages of drawdowns? Dean Knighton presented data showing that drawdowns can be used to obtain the interspersion among life forms of vegetation that John Mathisen had shown to be important for obtaining diversity of wildlife species. Additional research is needed in this area.

Fred Reid discussed the importance of drawdowns on invertebrates that form the food source for many species of wetland wildlife. He pointed out that invertebrate species have evolved specialized strategies in response to fluctuating water levels. These strategies must be understood if the manager is to duplicate invertebrate production that occurs in natural wetlands. Research on this subject is complicated by sampling problems that can easily lead to erroneous conclusions but this must not deter our quest for better information about these phenomena.

A number of papers were very specific in presenting instructions on how to go about constructing an impoundment. Sandy Verry showed that in the northern Lake States specific conductance can be a useful tool for determining water source for an impoundment when used in conjunction with topography, glacial geology, and soils data. It is then possible to select top candidate sites for impoundment construction. Glen Anderson presented further information on site selection and described various water control structures that have worked well on the Chippewa National Forest. Robert Farmes addressed the same subject and stressed the importance of careful pre-construction planning. He reviewed the various State and local groups that must be contacted and permits that must be obtained. Arlyn Linde drew from past experience in Wisconsin to set guidelines for manipulating vegetation to maintain desired species composition and interspersion. He pointed out that, without proper management, impoundments can easily result in monotypic stands of cattail.

Gerald Martz stressed the importance of public perception of water impoundments. Frequently what the public wants from impoundments may not agree with the wildlife management goals for which they were constructed. For example, impoundments are frequently designed for waterfowl and the public is interested in fishing. Ronald Poff also pointed out the magnitude of public interest in using impoundments for fishing. He illustrated how impoundments differ from natural lakes and some special fish management problems including invasion by rough fish. He furnished the manager with a number of useful but frequently expensive techniques that have been used in Wisconsin. Richard Buech identified another invading species that can cause problems for an impoundment engineer. This animal is often superior to man and usually with a different set of objectives. Numerous ingenious methods of outwitting beavers were illustrated but few worked well. Beavers remain an unsolved problem in impoundment construction. It is important that further research be conducted on total value of impoundments, as well as natural wetlands. We should not have to attempt justification of construction expense on the basis of wildlife use alone.

We found that the papers presented did an excellent job of reviewing the state-of-the-art of impoundment management. A number of new tools were made available for inclusion in a symposium proceedings; however, the complexity of the ecological systems being managed and our frequent lack of basic information means that no proceedings can serve all needs. Because we lack needed information in several areas, impoundment management is still more of an art than a science. The well trained, thoughtful manager intimately familiar with his own area is essential to good wildlife managment. This set of papers should furnish him with much helpful information but cannot replace his own ability to make intuitive decisions.

These new changes are coming under fire by conservation organizations and the Department of Interior as well as some members of Congress. However, the nationwide permit must be approved by the individual States, and to date some States, including Minnesota, Wisconsin, and Michigan, I believe, have not approved the nationwide permit under the new regulations. Thus in these States, at least, the old procedure still must be followed. Applications for Corps permits are made through the Office of the District Engineer. Engineering Form 4345 should be requested.

Information on the permit process should be obtained from the regulatory agencies early in the planning stages of an impoundment so that you may be prepared with the proper information when the time comes to submit the application. The process can be a difficult, time-consuming effort until one learns the permit requirements. Just remember that the regulations are designed primarily for the protection of the kinds of waters and wetlands we are all interested in.

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Knighton, M. Dean, comp.
Water impoundments for wildlife: a habitat management workshop. Gen. Tech. Rep. NC-100. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1985. 136 p.

Discusses many aspects of managing wildlife water impoundments in the western Great Lakes region. Political and biological justification, where and how to build impoundments, water-level management options, vegetation, water quality, invertebrate populations, and research needs are all considered.

KEY WORDS: Wetland management, waterfowl, low-head dams, water-level control, forests, fish.